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AN INVENTORY OF SCIENCE METHODS.

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THE DEVELOPMENT OF AN INVENTORY OF SCIENCE PROCESSES INCLUDED THE DESCRIPTION OF A MODEL OF INQUIRY AND AN INSTRUMENT TO SAMPLE THESE INQUIRY BEHAVIORS OF ELEMENTARY SCHOOL STUDENTS. THE BEHAVIORS OF SEARCHING, DATA PROCESSING, VERIFYING, DISCOVERING, ASSIMILATING AND ACCOMMODATING WERE IDENTIFIED AS COMPONENTS OF THE MODEL OF INQUIRY. THE TAB SCIENCE TEST WAS DESIGNED TO SAMPLE INQUIRY BEHAVIORS BY PRESENTING THE STUDENT WITH (1) A SPECIFIC PROBLEM, (2) A LIST OF CLUES TO HELP HIM SOLVE THE PROBLEM, AND (3) THE OPPORTUNITY TO GATHER CLUE DATA WHEN THEY ARE NEEDED. THE SUBJECTS WERE 2,519 FOURTH-, FIFTH-, AND SIXTH-GRADE STUDENTS IN 6 TEXAS SCHOOL DISTRICTS. AS IDENTIFIED BY INSTRUMENTS, THE STUDENTS REPRESENTED A RANGE OF TESTED INTELLIGENCE, SCIENCE KNOWLEDGE, SOCIOECONOMIC BACKGROUNDS, CHRONOLOGICAL AGE, AND READING ABILITY. THE VALIDITY OF THE TEST WAS DETERMINED BY USING CHI SQUARE ANALYSIS OF THE RELATIONSHIPS BETWEEN THE TEST SCORES AND STUDENT BEHAVIORS WHICH WERE PREDICTED FROM THE MODEL OF INQUIRY. IN ADDITION A RANK CORRELATION ANALYSIS OF THE RELATIONSHIP BETWEEN TEST SCORES AND TEACHER'S RATING OF STUDENTS WAS DETERMINED. (GC)

AN INVENTORY OF SCIENCE METHODS

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ACKNOWLEDGMENT

Specific acknowledgment is made of the insightful and creative work of Howard L. Jones of Syracuse University in developing the scoring system for the TAB Science Test.

INTRODUCTION

THE PROBLEM.

A major challenge to psychometricians is the assessment of problem solving or inquiry behaviors. Attempts have been made to (1) observe both lower animals and humans in problem situations and to infer the mental processes used by the subjects to solve problems. (See, for example, Thorndike, 1898; Morgan, 1894; Kohler, 1947; Tollman, 1948; Duncker and Krechevsky, 1939; Piaget, 1928). In addition, (2) human subjects have asked to verbalize their thoughts in problem situations in an attempt to observe problem solving behaviors more adequately (for example, Duncker and Krechevsky, 1939; Bloom and Broder, 1950; Duncker, 1945). Both of these methods are long and tiring for the subject and the investigator. However to supplant these methods of evaluating human behavior with a valid written test has been a difficult step.

Problem solving or inquiry may be defined as a reaction behavior to a psychological situation. Tests which measure a subject's reactions in new situations are exemplified by the maze tests. One such test, The Porteus Maze Test consists of a series of printed line mazes, steeply graded in difficulty in which the child must draw the shortest line to the maze without crossing over the boundary. Another example of this type of problem solving is the "Manikin Test" found in the Pintner Patterson Performance Scale. In this test the child is asked to assemble a crude wooden figure of a man from arms, legs, head and trunk.

Problem solving or inquiry may also be defined as a type of reasoning behavior. Reasoning in Russell's (1956) terms, is very similar to problem solving. In reasoning, however, any activity is limited to the manipulation of images, symbols and symbolically formulated propositions, rather than the overt manipulation of objects. One test to design this aspect of problem solving is the Davis-Eels Games.

> This test requires not reading. All instructions are given orally by the examiner. The content is entirely pictoral and consists of problems chosen from everyday life experiences of children in urban American culture. (Anastasi, 1961, 267).

The authors of this test recommend that the score be described, not as IQ, but as the Index to Problem Solving Ability (IPSA).

Guilford's factor analytic research resulted in the development of two tests, one of which is designed to measure "divergent thinking" and the other to measure "convergent thinking".

The factors of fluency, flexibility, and originality are described as "divergent thinking', or as Guilford describes it, "the kind of thinking that goes off in different directions". (Guilford, 1959, 381). In contrast "convergent thinking" leads to a single right answer determined by the given facts.

The Primary Mental Abilities Test and the Differential Appitude Test contain sections designed to measure verbal and abstract reasoning. In addition general achievement batteries such as the Sequential Test of Educational Progress and the Metropolitian Achievement Test contain sections which are used to measure problem-solving and reasoning. It is obvious, however, from the reviews found in Buros (1959), that few available test scores can be interpreted to indicate the steps that a student uses in inquirying into or solving a problem. In the past

> . . . test constructors have tried to construct items which were so structured that by analyzing the students' answers one could infer the problem-solving process which the student used. . . . By knowing the answer choice the student made we could then know the method he used to solve the problem. Verbal problem-solving in general has shown that the types of items and variety of subject matter in which this technique can be used are few. Although it may appear that the process can be inferred, studies usually show students can come up with ways and answers often correct that no teacher seemed to have anticipated. When accurate knowledge of the process is required, actual recording of students' problem solving processes can be considered generally preferable in the majority of cases to inferences from the product. (Bloom, 1956, p.127).

Needed then, is an instrument which would sample student behaviors as he solves a problem or inquires.

RELATED RESEARCH

Several attempts have been made to examine and evaluate the individual inquiry processes of behavior of students. One example is the Questest developed by Suchman (1962). In this test special films are used to present problem episodes to individual elementary school students. The students are then asked questions which the examiner answers only with a "Yes" or "No" response. The entire session is tape recorded and subsequently analysed. Following this question asking session the student is given a paper-and-pencil test designed to measure (1) what principles he has discovered through inquiry session; (2) which of the necessary conditions he can identify and how accurately he can identify them; and (3) how many objects, conditions, and events of the episode he has positively identified and correctly assumed. In this manner, inquiry or problem solving behaviors are evaluated by noting how much information, and how many relationships and principles are induced from the gathered information.

> This is the "end-product" approach which is founded on the assumption that if all factors are equal, the child who is a better inquirer will obtain more data and will learn more from the data he obtains. (Suchman, 1962, p. 65).

The processes used by the children, on the other hand, are analyzed by Suchman in terms of the structure and function of the questions asked, the fluency of the questioning, the relative frequency of the various question types, the over-all plan or strategy used in the grouping or sequency of the questions.

Another example of the measurement of problem solving behaviors is Read's (1949) Picture Test. This instrument is described as measuring the ability to use the scientific method. According to Read,

> . . . a test of the ability to think in the scientific method pattern should require the testee to go through the steps of a scientific method in order to arrive at the correct solution of the problem of the test. (Read, 1949, p. 361).

Accordingly "failure to apply these steps should result in a low score on the test".

Rimoldi (1955) described an attempt to analyze the processes of thinking and problem situations rather than its end-product as indicated by a certain answer. Additional studies by Rimoldi (1955) and Eccles (1959) represent attempts to analyze students' behaviors in science problem situations by using a series of cards on which scientific information was found. Analysis of the sequence of card choice was taken as an indication of the steps used by the subjects in problem solving or inquiry.

Glaser, Damrin and Gardiner (1952) were among the first to propose the use of a tab-item test to measure problem solving behaviors. As described by Glaser:

> A Tab-Item presents an examinee with the following: a description of the problem situation; a series of diagnostic procedures which if employed might yield information relevant to the solving of the problem; and a list of specific solutions one of which is correct. In taking the test the examinee selects any number of procedures presented which he thinks will provide him with the information necessary to solve the problem.

> The resulting information from whatever procedures the examinee chooses are given him at the time he selects them. This is accomplished by giving the results or consequences of a procedure in the form of written or diagrammatic information which is covered by a tab fastened to the page. When the examinee selects a procedure he rips off the tab and obtained the results of the procedure he has "performed". In a like manner an examinee is informed of the correctness or incorrectness of his choice of a solution. An examinee works on an item until he has the correct solution denoted by the word "Yes" under the corresponding tab. (As quoted by Bloom, 1956, p. 127-;28).

Thus, in the tab format, the sequence or tabs pulled gives an indication of the problem solving or inquiry behaviors of the subject.

Cross and Gaier (1955) also used the Tab Format when they developed the Balanced Problem Test (BPT). The development of the BPT was an attempt to measure the extent to which an individual selects and makes effective use of principles in contrast to using factual information in problem solving. The tab format allowed the examinee to remove irreplaceable tabs from the test. Under these tabs was specific data that could be used in the solution of the problem.

An instrument developed by Butts (1965), based on the tab format was used to study patterns of problem solving of college students. This instrument presented the student with (1) a specific problem; and (2) a series of questions pertaining to the problem. Answers to these questions were covered by numbered tabs. Patterns of problem-solving behaviors were inferred from the order of tabs pulled by the subjects. Jones (1966) modified this test to measure an instrument to inquiry skills of sixth-grade students. As redesigned, the instrument consisted of four sections: (1) in a written response the student predicted what would have happened in a described situation; (3) the student gathered data concerning the problem by pulling numbered answer tabs from questions he choses to ask. Each of these questions were structured so that the answer is a "yes" or "no" response. In part (4) the student applied his gathered knowledge from section (3) to explain why the situation happened as it did. Each numbered tab in section (3) was placed on an attached card when it was removed from the test by the student. These tabs formed a sequential record of the data selected by the student in the solution of the problem. Analysis of written responses in section (2) and (4) gave an indication of the problem-solving or inquiry behavior employed to solve the problem.

In terms of the analysis of problem solving behavior it is noted that in the literature there is a lack of agreement concerning whether or not there is a pattern that can be employed to solve all problems by students. Tests designed to measure problem solving or inquiry behaviors have given little or no indication of how these behaviors are used by children to arrive at answers.

OBJECTIVES

There were three objectives in the development of an inventory of science methods using the TAB Format:

a. The development of the TAB Science Test.

b. The development of a manual for administering the TAB Science Test.

c. The establishment of norms of the TAB Science Test including reliability and validity data.

METHOD

THE DEVELOPMENT OF THE TAB SCIENCE TEST.

If inquiry is a learned behavior some students may be expected to be more proficient inquirers than others. However, the evidence of measurable differences in inquiry among students rerequires a clear definition or description of these behaviors.

As noted previously, there is a notable absence of an unambigious description of specific student behaviors involved in inquiry. Suchman's inquiry studies represent one attempt to identify and describe specific inquiry behaviors of students. He proposed that, given a science problem to investigate the student should be led to comprehend that there are some more productive ways of inquiry that might help them explore the problem. Suchman (1962) analyzed how inquiry was conducted by the elementary school student. He has described a student's action in inquiring into a problem situation as (1) searching, (2) processing data, (3) discovering, and (4) verifying. However,

> while none of these actions is unique to inquiry they are all essential to it, and in combination form a cycle of operation that characterizes the inquiry process. (Suchman, 1962, p. 5).

It also has been hypothesized that what is found through inquiry by a child often leads to the expansion of his conceptual systems through what Piaget (1950) calls assimilation and accommodation.

These five activities (searching, processing data, discovering, verifying, assimilating-accommodating) were the specifics for a model to clearly identify and define inquiry behaviors. In this model the actions of inquiry are not separate and discrete entities. Each activity is dependent on others that have preceded or will precede it. A representation of the model of inquiry behaviors is illustrated in Figure I.

A student who finds himself in a problem situation may search and process data. However, his searching and data processing operations are dependent on his past searching, data processing, verifying, discovering, assimilating and accommodating behaviors are also dependent upon his searching and data processing behaviors.

Inquiry thus is represented as a cyclic operation. The end-products of inquiry are the expansion of conceptual systems and the abilities to use these expanded systems to produce inquiry into other situations.

In a common essay or short answer test inquiry is measured by assuming that if a student knows the answer to the proposed problem he is a proficient searcher, data processor, discoverer, verifier, assimilator and accommodater. In the essay or short-answer test, no indication is given of the behaviors that the student employs while inquiring into the problem situation.

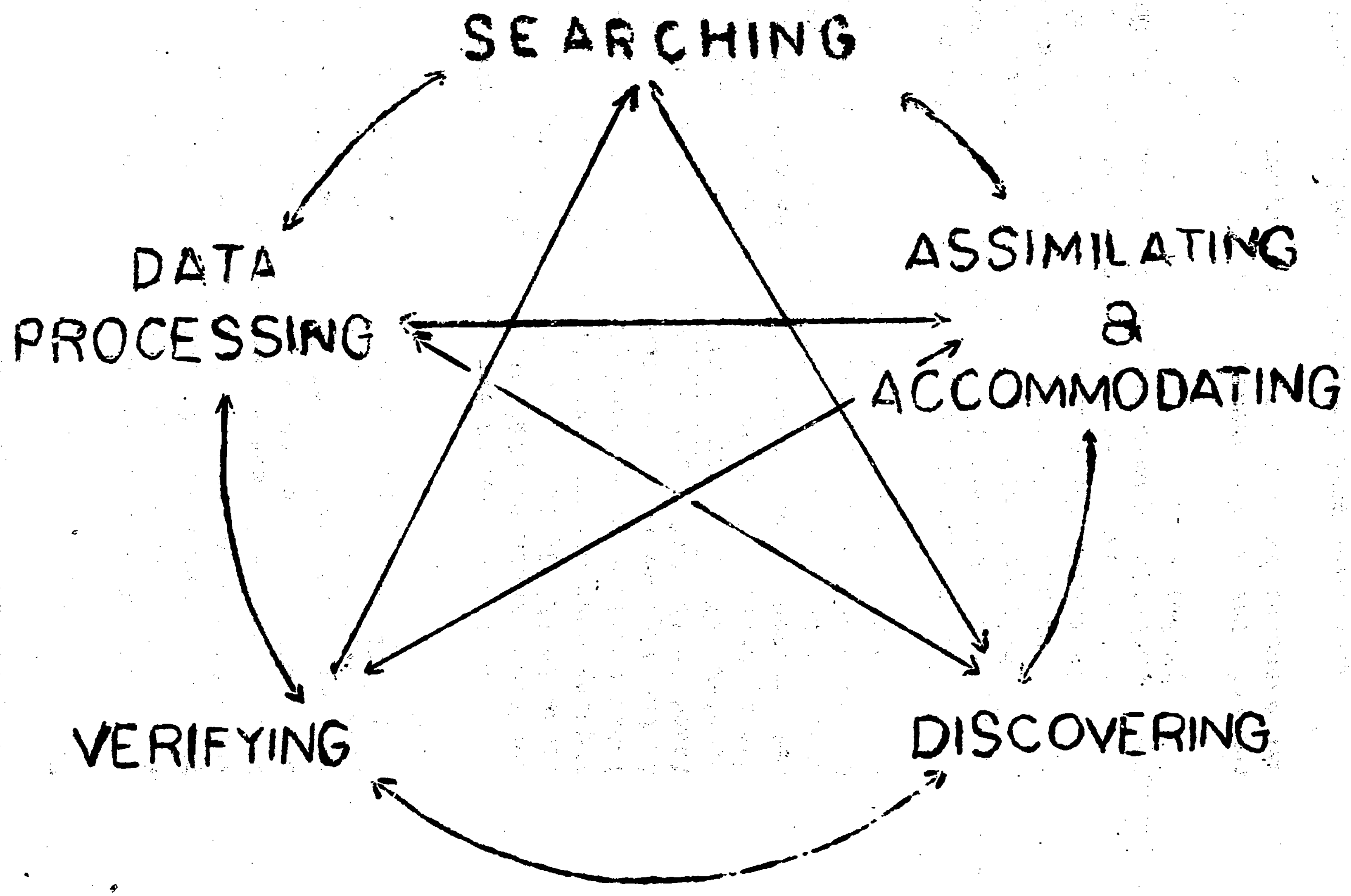
With the TAB Science Test the measurement of the behaviors presented in the inquiry model are inferred from the student's performance. That is, the inquiry behaviors of a student are evaluated by analyzing what he does when (1) searching, (2) processing data, (3) discovering, and (4) verifying. In addition, the student is allowed to apply conceptual understandings to new situations; an illustration of his assimilation and accommodation of concepts.

The TAB Science Test, using the Tab-Item Format, samples the behaviors of inquiry as identified in the inquiry model. For each of the two parallel forms of the TAB Science Test. There are four sections:

Section 1:

The student is presented with a science problem in the form of a physics problem-focus film. He is then asked to select from a set of explanations the one that he thinks to be the most correct. These explanations were selected from oral explanations given by

FIGURE 1. A MODEL OF INQUIRY BEHAVIOR



elementary school students in classroom situations. In this first section the student either selects the correct answer or the incorrect answer. Knowledge of his selection gives an indication of his behavior as a verification or discovery type. If the student hypothesized the correct solution of the problem before gathering clue data, he is verifying a solution. If the student does not know the correct solution to the problem before gathering clue data, his solution is a discovery.

Section II.

In the second section the student is presented with several (10 to 16) clue questions which he may use to help him solve the problem. The answer to each question is covered by a laminated tab attached to the test with double edged masking tape. If the student wishes to ask a question he is free to remove the corresponding tab to find the answer. However, before he is allowed to remove any tabs the student is instructed to read all of the clue questions. This precaution is taken to discourage the student from taking the "cafeteria" sequence; that is taking tab A, B, C . . .

Each question in Section II was selected from groups of questions asked by students in similar problem situations. Previous to the draft of the test, 30 one-half hour to one hour inquiry sessions with 4th-5th-and 6th-grade students were held. These sessions were based on the format developed by Suchman (1962). In the inquiry sessions students were shown the identical film found in the TAB Science Test. They were asked to solve the problems after gathering clues by asking questions of the investigators. In answering the questions one basic restriction was imposed: the question had to be structured so as to be answerable by a "yes" or a "No" response. This restriction eliminated open-end questions and forced the students to focus and structure their queries. As Suchman (1962) indicated:

> For example the child may not ask "How did the heating affect the metal?" but he may ask "Did the heating change the metal into a liquid?" In the first instance the child does not state specifically what information he wants. He is asking the teacher to conceptualize relationships for him - that is to teach him something - this is the very anthesis of what inquiry is designed to do. (Suchman, 1962, p. 30).

For this reason the questions in Section 2 of the TAB Science Test are answered by "Yes" or "No" responses.

Questions most frequently asked by students during the inquiry session were identified. These questions were analyzed by a panel of seven judges who tested each clue question for scientific accuracy, question value, (is the question relevant, additional, or irrelevant to the solution of the problem?) and question type (what kind of information is included in the question.) Interclass correlation coefficients were calculated and are presented in Table I. Complete categorization of the TAB Science Test questions are found in Appendix C.

TABLE I

Judgmental Reliability Coefficients of TAB Science Test Questions.

Ia. Question value.

Test Form and Part	Intraclass Correlation
A - 1	0.713
A - 2	0.715
B - 1	0.796
B - 2	0.816

Ib. Question Type

Test Form and Part	Intraclass Correlation
A - 1	0.668
A - 2	0.794
B - 3	0.812
B - 2	0.806

Analysis of the students performance in Section II gives an indication of his searching and data processing behaviors. A student proficient in searching should not choose clues which are irrelevant to the problem. A student proficient at data processing should organize data into logical and nonredundant sequences of clue questions.

Section III

In Section III the student is presented with the same series of explanations as found in Section I. However, to the right of each of the explanations is a numbered TAB. When the student is ready to select one of the explanations, he is free to pull the TAB and see if he is correct. A correct answer has a "Yes" response under the numbered TAB.

In Section III knowledge is obtained of the success or lack of success of the student's verification or discovery behaviors. If the student hypothesizes the correct solution in Section I and then (immediately after gathering clues in Section II) selects the correct solution again in Section III he is a more successful verifier than the student who selects the incorrect solution in Section III before deciding on the correct solution. This same trend holds for successful and nonsuccessful discoverers.

Section IV

At the end of each test two multiple choice questions are asked of the student. These questions are used to evaluate the student's ability to transfer discovered or verified concepts. Thus, the section gives a measure of assimilation and accommodation behaviors.

Administering the TAB Science Test

A separate answer sheet is used to record questions asked by the student on the TAB Science Test. Each TAB covering the answer on Section II is lettered to correspond with the lettered question. For example, a "G" is printed on the tab covering the answer to question "G". Also each TAB covering the answer in Section III is numbered to correspond to the numbered explanation. After removing the TAB from the test the student places the TAB on the answer sheet in the space provided. Since each TAB is identified by a letter or a numeral the TABS on the sheet form a sequential record of the information and explanations selected by the student. This procedure supplies the number, type and sequence of questions asked by a student in solving a problem. Thus it indicates not only the student's problem solution but also his inquiry behaviors.

To facilitate the use of the test the student copies the letters and the numerals of the TABS on his answer sheet. Then he replaces the TABS on the instrument in correct alphabetic or numeric order. Using this procedure the tests are ready for immediate re-use while a complete sequential record of TABS pulled by the student is available on the answer sheet. In the case of Parts A-2 and B-2 where Section IV is included, adequate space is provided for an answer sheet for the student to answer the two concept-transfer questions.

An example of the use of the answer sheet is found in Figure 2. Copies of the TAB Science Test, Forms A and B are found in Appendix A.

FIGURE 2.TAB SCIENCE TEST NAME ____________________

ANSWER SHEET

CODE ____________________

2. Student chooses clue tabs and places them in "TABS" column

TABS	
A	A
M	M
C	C
6	6
K	K
N	N
2	2

3. Student copies list of tabs and replaces tabs on test.

1. Student chooses explanations

1.
2.
3.
4.
5.
6.

QUESTION #1

4. Student answers transfer questions.

a.
b.
c.
d.

QUESTION #2

a.
b.
c.
d.

SCORING THE TAB SCIENCE TEST.

A crucial aspect in the development of the TAB Science Test was the identification of a scoring technique that reveals specific inquiry behaviors. Suggestions for scoring similiar instruments have included:

(1) Compare the order of tab pull of students with those who are proficient in inquiry against "optimal sequence" of tab pull.

(2) Use the sum of "utility scores" of tabs (Rimoldi, 1955) which are defined as ratios between the number of times that individual clue items are selected in the total number of subjects in the test sample.

(3 Use the number of TAB questions chosen by the student before selecting the final correct answer or use an average or minimum number of tabs as a criterion.

(4) Use a weighted-error count where the clue tabs are weighted in reverse relation to their relevance in isolating the answer to the problem.

In this study the weighted-error count that was proposed by Glaser, Damrin and Gardner (1952) was selected as a major basis behind scoring of the TAB Science Test. In this method the student is penalized in chosing irrelevant and additional information clues more so than he is in choosing relevant clues.

Another important aspect considered in the scoring procedure of the TAB Science Test is the order of TAB pull. While it is recognized that not all problems maybe solved in a similar manner it is important that logic guide the inquiry behaviors of students regardless of what method is used to solve a specific problem. For example, a student inquiring into Part A-1 of the TAB Science Test finds the following question in Section II.

Question B.	Was the water in the bottle with the yellow balloon before the bottle was put on the fire?	YES
I.	Did the water with the yellow balloon contain something besides air?	YES

It is understandable that if a student ask question "I" a logical choice to follow would be question "B". However, if he ask question "B" then question "I" would add nothing to his storehouse of knowledge. It would be an illogical question.

A computerized scoring system was developed to score the <u>TAB Science Test</u>. This scoring system takes into consideration number, type and value of clues obtained by the student. Also taken into consideration is the order of tab pull. Flow sheets such as that in Figure 3 (and in Appendix D) were developed for each test problem. On these sheets letters indicated the clue questions and numerals indicate the problem solution. Arrows indicate possible connections between clues and problem solutions, and between clue questions and other clue questions. Arrows which are blocked (—//—>) indicate an illogical clue gathering sequence. Double pointed arrows (<—//—>) indicate redundancies.

Low numerical values are assigned to relevant clue questions, to logical and non-redundant sequences and to plausible problem solutions. Subtraction of the sum of all tab and sequence scores counted against a student from the constant gives the final score. The constant is the maximum number of points that could be counted against any scoring sequence.

Table 2 reveals the scoring system used by the <u>TAB Science Test</u>.

For each student a page of data is available in the format exemplified by Figure 4.

The student's name and the identification number for his class, sex, and <u>TAB Science Test</u> Form are found at the top of Figure 4. Below this identification are two graphs. The graph at the top of the figure represents the first problem of the <u>TAB Science Test</u> Form B (The Air Sled). Bordering the graph as the abscissa are numerals 1 through 14 bordering the graph as the ordinate are numerals 1 through 4 and letters A through J.

An asterisk (*) on the graph indicates the specific clue TAB that was selected by the student. For example in Figure 4, it can be noted that the first clue TAB selected by this student was TAB E. After TAB E was selected, the other TABS selected were TAB J, A, C, G, D, H and B. After pulling these TABs the student pulled TAB 2 from the answer page. Under TAB 2 was a "Yes" response so the student knew he had found the solution to the problem.

The same format as described above is followed in interpreting the graph found in the lower half of Figure 4. This lower graph describes the student's behavior on <u>TAB Science Test</u> Form B Part 2 (The Bi-Metallic Strip). At the lower left of the figure are six numbers 27*, 68 (10,0), 95, 266.

The 27 represents the number of points counted against the student by invoking the test scoring system as represented in the upper graph. This number is the sum scores assigned to each tab

TABLE 2

Scoring System for the TAB Science Test

Question Type or Pattern	Operation Performed on Child's Score	Points
1. Relevant Question	Add	1
2. Additional Question to a Correct Explanation	Add	2
3. Additional Question to an Incorrect Explanation	Add	3
4. Additional Question to No Given Explanation	Add	4
5. Irrelevant Question	Add	5
6. Correct Explanation	Add	5,10*
7. Incorrect Explanation	Add - Depending on Choice	10, 15, 20 30, 40, 50, 60**
8. Redundancy Pattern ($\leftrightarrow\!\!\!\!/\;$)	Add	5
9. Illogical Pattern ($\not\longrightarrow$)	Add	5
10. Section 4 - - Incorrect Response	Add	10

* 5 for parts A-1, B-1; 10 for parts A-2, B-2.
** 10, 15, or 20 for parts A-1, B-1; 20, 30, 40, 50, or 60 for A-2, B-2.

FIGURE NO. 3

SYSTEM ANALYSIS OF TAB SCIENCE TEST

PART B-2

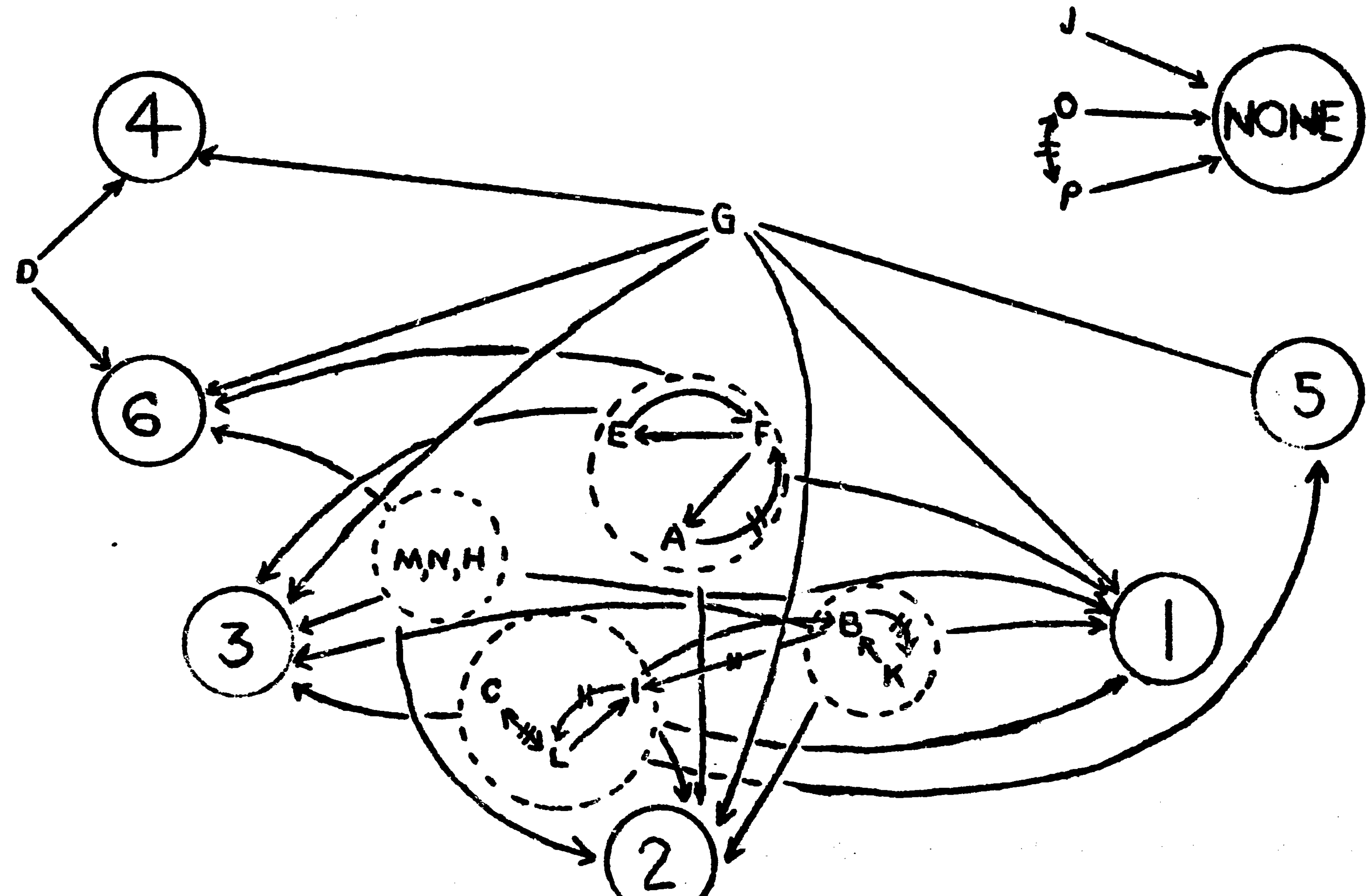
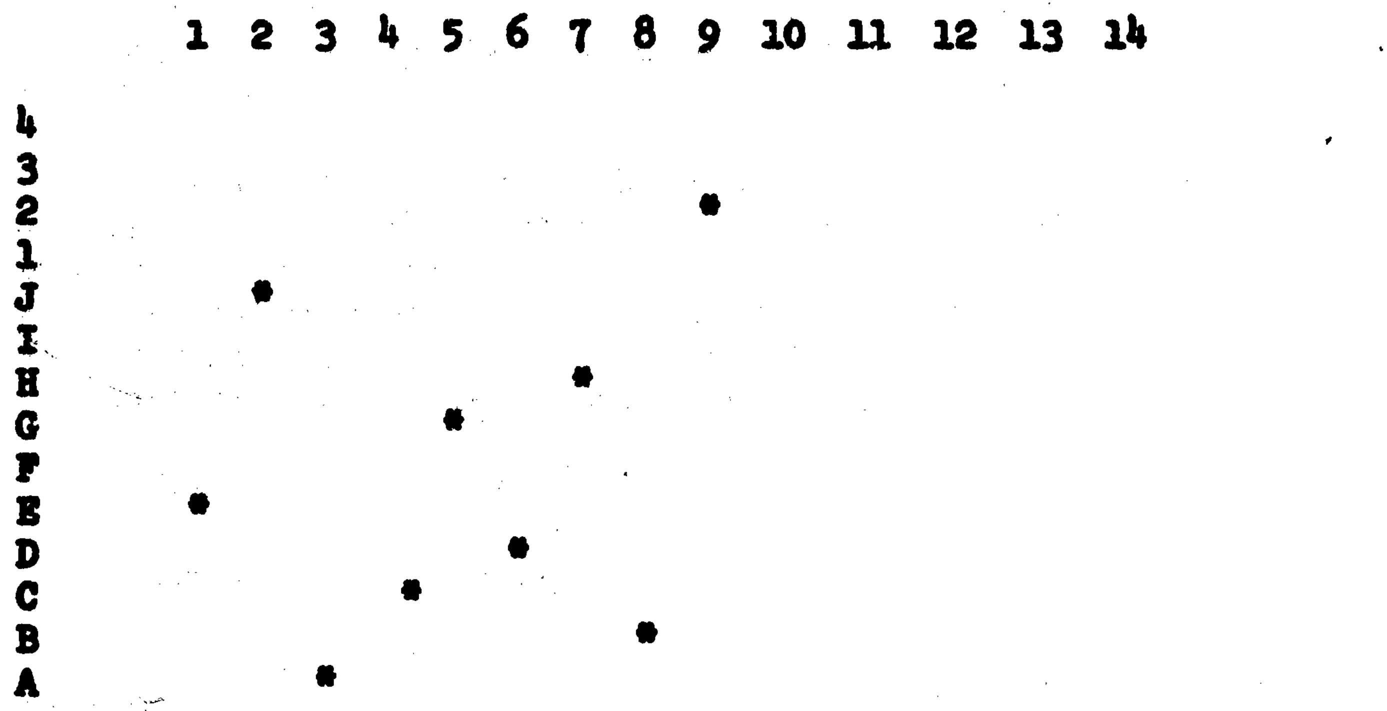


FIGURE 4 THE TAB SCIENCE TEST COMPUTER PRINT-OUT

NAME 834MB



27*
68 (10,0)
95
266

(TAB E - 1, TAB J - 1, TAB A - 1, TAB C - 4, TAB G - 3, TAB D - 5, TAB H - 1, TAB B - 1, TAB 2 - 5), and (2) the scores assigned to illogical or redundant sequences chosen by the student. (TAB E followed by TAB A is illogical hence E $\longrightarrow$ A = 5 points.)

The 68 represents the number of points counted against the student by invoking the test scoring system as represented in the lower graph.

The (10,0) indicates the student's proficiency in transfering concepts into similar problem situations. If the student answers either question correctly he is assigned a score of "0". If he answers either question incorrectly he is assigned a score of "10". In the case represented in Figure 4 the student missed the first question but correctly answered the second.

The 95 is the sum of 27 and 68 the combined student's score.

The 266 is the difference between 95 and a constant of 361.

Since the total number of points that can be earned by a student on Form B of the TAB Science Test is 361, the examinee's final score is obtained by subtracting the sum of the top graph score (27) and the bottom graph score (68) from this constant.

The asterisk indicates that for the problem described by the top graph the student hypothesized the correct solution before gathering clues. In the second problem (bottom graph), the student did not correctly hypothesize the problem solution, hence, no asterisk is included with his score. This asterisk gives an indication of the student's verification or discovery behaviors. If the asterisk is present, it is assumed that the student is verifying; if the asterisk is missing a correct solution that the student finds will be a discovery.

ESTABLISHING THE NORMS FOR THE TAB SCIENCE TEST.

The Sample: The TAB Science Test norms were established based on 2,519 fourth-, fifth-, and sixth-grade students in six Texas school districts. In each of these school districts a wide range of socioeconomic backgrounds, tested intelligence, science knowledge, and reading scores were exhibited by the subjects. In all cases, the subjects were administered the TAB Science Test in groups of not less than 25.

The data collected from the TAB Science Test scores are presented in Table III.

TABLE III

TAB SCIENCE TEST DATA

Test Form	Number Taking Test	Range of Raw Scores	Possible Maximum Score	Possible Minimum Score	Mean Score	Stand. Dev.	Median Score
A	1264	16-364	364	0	296	51.5	310
B	1255	15-345	346	0	260	58.5	274

Specific analysis of the readability, validity and reliability of the TAB Science Test were made.

RESULTS

READABILITY OF THE TAB SCIENCE TEST

The readability of the TAB Science Test was determined by using the Dale-Chall and the Spache Readability Formulas. Readability was evaluated (1) by using only those words in the test proper and (2) by using all the words on the TAB Science Test including the instructions. The results of this analysis are presented in Table IV.

TABLE IV

Readability Scores of the TAB Science Test.

	Spache Formula	Dale-Chall Formula
Part A-1 (No Instructions)	3.7	4.6
Part A-1 (Instructions)	3.9	4.9
Part A-2 (No Instructions)	5.4	4.9
Part A-2 (Instructions	7.8	5.0
Part B-1 (No Instructions)	3.4	4.4
Part B-1 (Instructions)	3.7	4.8
Part B-2 (No Instructions)	3.7	4.7
Part B-2 (Instructions)	4.3	4.8

Thus it can be seen that if the written directions are ignored (the directions are also given orally) the readability of the test selections are acceptable to most students having a fourth-grade reading vocabulary.

VALIDITY.

Concurrent validity of a test demands some external criterion. Using the external criterion of teacher ratings, teachers were asked to rank their students in terms of the criterion "Systematic Problem Solvers". Rankings were obtained from paired comparisons using multiple rank analysis as described by Gulliksen and Tucker (1959). Twelve of the twenty-two teacher ratings of students were significantly correlated with the rankings obtained from TAB Science Test scores. These correlations are found in Table V.

Construct validity is another indicator that the test measures what it purports to measure. One analysis which would indicate this would be the agreement with the proposed model of inquiry. A Chi square analysis indicated that the TAB Science Test does differentiate among nonproficient and proficient verifiers, data processors, searchers, discoverers, assimilators and accommodators. As in Table VI, VII, VIII, IX, AND X, higher scoring students were found to be more successful in individual inquiry skills than lower scoring students.

RELIABILITY

The Reliability of the TAB Science Test was determined by calculating the coefficients of equivalence and internal consistency. Comparing 446 students scores on both forms of the TAB Science Test, coefficients of equivalence were obtained:

$$r_{ab} = .420 \qquad (N = 238)$$

$$r_{ba} = .365 \qquad (N = 208)$$

Coefficients of correlation were also calculated between scores obtained on the first problem of each test with subsequent scores on the second problem of each test. The following coefficients of internal consistency were obtained.

$$r_{\text{form A}} = .497$$

$$r_{\text{form A}} = .532.$$

DISCUSSION

The TAB Science Test was developed to measure student inquiry

TABLE V

RANK CORRELATION ANALYSIS OF TAB SCIENCE TEST RESULTS AND TEACHERS' RATINGS

Teacher	TAB Science Test Form	Rank Correlation	t Value	Number of Subjects	Level of Significance
A	B	0.009	0.041	22	$0.20 <$
B	A	0.019	0.092	24	$0.20 <$
C	A	0.126	0.554	21	$0.20 <$
D	B	0.149	0.641	22	$0.20 <$
E	B	0.158	0.716	22	$0.20 <$
F	B	0.228	1.123	25	$0.20 <$
G**	A	0.240	0.934	17	$0.20 <$
H**	B	0.384	1.501	15	$0.20 <$
I	A	0.390	1.587	16	$0.10 < x < 0.20$
H*	A	0.506	2.115	15	$0.05 < x < 0.10$
J**	A	0.533	3.233	23	$0.001 < x < 0.01$
G*	B	0.563	2.638	17	$0.01 < x < 0.02$
K*	A	0.568	3.932	27	< 0.001
J*	B	0.599	3.429	23	$0.001 < x < 0.01$
K**	B	0.644	4.209	27	< 0.001
L**	B	0.720	5.126	18	< 0.001
L*	A	0.715	4.321	18	< 0.001
M	A	0.711	4.872	25	< 0.001
N	B	0.616	4.012	27	< 0.001
O	B	0.598	3.451	23	$0.001 < x < 0.01$
P	A	0.657	4.399	27	< 0.001
Q	B	0.321	1.622	25	$0.10 < x < 0.20$

* and ** refer to the classes which were administered both forms of the TAB Science Test. Those teachers' rankings marked * were compared against scores on the first form of the test administered. Those marked ** were compared against scores on the second test administered.

TABLE VI

Comparison of Data Processing Behaviors with TAB Science Test Scores

	Students Choosing No. Redundant or Illogical Sequences		Students Choosing Redundant or Illogical Sequences	
	Form A	Form B	Form A	Form B
Students with Highest 50 Scores	46	45	4	5
Students with Lowest 50 Scores	6	12	44	38

$x^2_{\text{Form A}} = 60.94$

$x^2_{\text{Form B}} = 41.78$

$x^2_{.001} = 10.83$

TABLE VII

Comparison of Verification Behaviors with TAB Science Test Scores

	Students Demonstrating Successful Verification Patterns		Students Demonstrating Less Successful Verification Patterns	
	Form A	Form B	Form A	Form B
Students with Highest 50 Scores	32	27	2	0
Students with Lowest 50 Scores	2	1	14	12

$x^2_{\text{Form A}} = 29.66$

$x^2_{\text{Form B}} = 35.17$

$x^2_{.001} = 10.38$

NOTE: The sum of the number of students showing discovery patterns plus the number of students showing verification patterns equals 100 for each form because there are two sub-problems in each test.

TABLE VIII

Comparison of Discovery Behaviors With TAB Science Test Scores

	Students Demonstrating Successful Patterns		Students Demonstrating Less Successful Patterns	
	Form A	Form B	Form A	Form B
Students with Highest 50 Scores	66	73	0	0
Students with Lowest 50 Scores	5	7	79	80

$x^2_{\text{Form A}} = 117.96$

$x^2_{\text{Form B}} = 143.12$

$x^2_{.001} = 10.38$

TABLE IX

Comparison of Assimilation and Accommodation Behaviors With TAB Science Test Scores

	Both Transfer Questions Answered Correctly		First Question Correct Second Incorrect		First Question Incorrect Second Correct		Both Transfer Questions Answered Incorrectly	
	Form A	Form B	Form A	Form B	Form A	Form B	Form A	Form B
Students with Highest 50 Scores	28	25	11	10	11	15	0	0
Students with Lowest 50 Scores	1	3	12	13	11	6	26	28

$X^2_{\text{Form A}} = 33.73$

$X^2_{\text{Form B}} = 32.44$

$X^2_{.001} = 16.27$

TABLE X

Comparison of Searching Behaviors with TAB Science Test Scores.

	Students Choosing No. Irrelevant Clue Tabs		Students Choosing Irrelevant Clue Tabs	
	Form A	Form B	Form A	Form B
Students with highest 50 Scores	44	41	6	9
Students with lowest 50 Scores	7	10	43	40

$x^6_{\text{Form A}} = 51.86$

$x^2_{\text{Form B}} = 36.01$

$x^2_{.001} = 10.83$

Students who participated in the development of this test were exposed for the first time to an entirely different testing experience than that to which they were accustomed. One might ask what effect did the test format have on the student's final score. Was the testing measuring, in part, the degree to which the student could follow directions and acclimate himself to a new test environment? Was the test itself a learning experience? Would TAB Science Test scores be more stable and consequently a more valid measure of inquiry if the student were instructed on the test format? Would a practice test included in the test booklet before the two test problems be a suitable means for such instruction? In the administration of this test the format was explained to the group and the group participated in the use of the format, however, it may be questioned if this was adequate practice with the new device for testing.

One measure of concurrent validity of the TAB Science Test was the relationship between TAB Science Test scores and teachers' rankings of their students in terms of the criterion "Systematic Problem-Solving". If teacher judgment of systematic problem solving - a criterion not usually a major interest in assigning grades to students - is such that the criterion is ambigious or not completely agreed upon as a single dimension criterion, then further study is needed to identify those factors that teachers consider as part of inquiry or problem-solving behaviors.

No significant correlation was found between scores on the TAB Science Test and chronological age. Because of the limited age range of the students of this study, perhaps the results cannot be compared with the results of studies of Piaget, Biber and Harter. However, in the analysis of this the data on the TAB Science Test, no trend was found that pointed toward the existence of a relationship between chronological age and productive inquiry. Could this result be interpreted in the light of Russell's view that age changes do not produce essential changes in patterns or productivity of problem-solving. Further study is needed on the effectiveness of the TAB Science Test as a measure of inquiry at age levels other than grades four, five and six. For example, are there differences in the inquiry methods exhibited by elementary school students, junior high school students, and high school students?

CONCLUSIONS.

Evaluation of inquiry requires an unambigious definition of the specific cognitive behaviors involved in inquiry. This means that there is a sampling not just of the end-product of inquiry, but of the process by which the individual arrives at the solution to a problem. The proposed model of inquiry implies specific directions for the development of an instrument to measure the behaviors.

As illustrated by the student performance on the TAB Science Test the proposed model of inquiry appears to be a meaningful tool by which to appraise student behaviors. The TAB Science Test is one way to define, isolate and measure the processes by which a problem is solved, rather than securing just the solution to the problem.

SUMMARY.

The development of an inventory of science processes included the description of a model of inquiry and an instrument to sample these inquiry behaviors of elementary school students. The behaviors of searching, data processing, verifying, discovering, assimilating and accommodating were identified as components of the model of inquiry.

The TAB Science Test was designed to sample inquiry behaviors by presenting the student with (1) a specific problem; (2) a list of clues to help him solve the problem; and (3) the opportunity to gather clue data when they are needed.

The subjects tested with the TAB Science Test were 2,519 fourth-, fifth-, and sixth-grade students in six Texas school districts. As identified by the instruments used in this study, the students represented a range of tested intelligence, science knowledge, socio-economic backgrounds, chronological age, and reading ability.

The validity of the TAB Science Test was determined by using a Chi Square Analysis of the relationships between the TAB Science Test scores and student behaviors of searching, data processing, verifying, discovering, assimilating and accommodating which were predicted from the model of inquiry. In addition using a Rank Correlation analysis a relationship between TAB Science Test scores and teacher's rating of students was found.

The reliability of the TAB Science Test was determined by calculation of coefficients of equivalents (.365 and .420) and coefficients of internal consistency (.497 and .532).

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APPENDIX A

The films selected for the test were designed for the Illinois Inquiry Training Study for the explicit purpose of presenting problems to children. The chief advantages of the films are (1) they present data in graphic form and make use of continuous action to do so, and (2) they insure the uniformity of problem stimulus. In the two forms of the <u>TAB Science Test</u>, there are four films, one each for Parts A - 1, B - 1, A - 2, and B - 2. The films and the problems they pose are:

A - 1 <u>Relative Expansion of Air and Water Under Heat.</u>

Two flasks are covered with balloons identical except for color. In one flask is air and a little water; in the other, there is only air. When the flasks are heated, the balloon covering the flask containing the water expands the greatest amount. The question is asked at the beginning of the film - - "WHY DOES ONE BALLOON GET BIGGER THAN THE OTHER?"

B - 2 <u>Air Sled.</u>

An air sled is glided over a level board. The sled moves more easily when the balloon is inflated and the rush of air from the balloon forms a cushion of air between the sled and the level board. When the balloon is deflated, there is considerably more resistance to movement. The question is asked at the beginning of the film - - "WHY DOES THE BOARD MOVE EASILY AT FIRST BUT NOT LATER?"

A - 2 <u>Boiling Water by Cooling.</u>

A pyrex flask is heated until the water inside the flask boils. The flask is then removed from the heat source and stoppered after the water ceases boiling. Cold water is poured over the outside of the stoppered bottle. The water inside the flask boils once again. The question is asked at the beginning of the film - - "WHY DOES THE WATER BOIL THE SECOND TIME?"

B - 2 <u>Bimetallic Strip.</u>

A bimetallic strip is heated and it bends. When immersed in cold water, it straightens. The question is asked at the beginning of the film - - "WHY DOES THE BLADE BEND AND THEN STRAIGHTEN OUT?"

These films were selected for their clearness in presenting a problem, their relative difficulty, and the number of relational constructs necessary for their solution. Two films were selected for each form to insure a range of difficulty. Classroom experience indicated that the complementary films for each test form (A-1 vs. B-1; A-2 vs. B-2) represent nearly equivalent difficulty as problem stimuli for children in grades four, five, and six.

TAB TEST

FORM A

THE TAB INVENTORY

OF

SCIENCE PROCESSES

WHY DOES ONE BALLOON GET BIGGER THAN THE OTHER?

Put a check mark by the answer that you think is most correct.

1. The yellow balloon got larger because it was easier to blow up than the pink balloon.

2. The yellow balloon got larger because the bottle with the yellow balloon held more air than the bottle with the pink balloon. Because there is more air in the yellow balloon, the heat makes the air expand more and makes the balloon bigger.

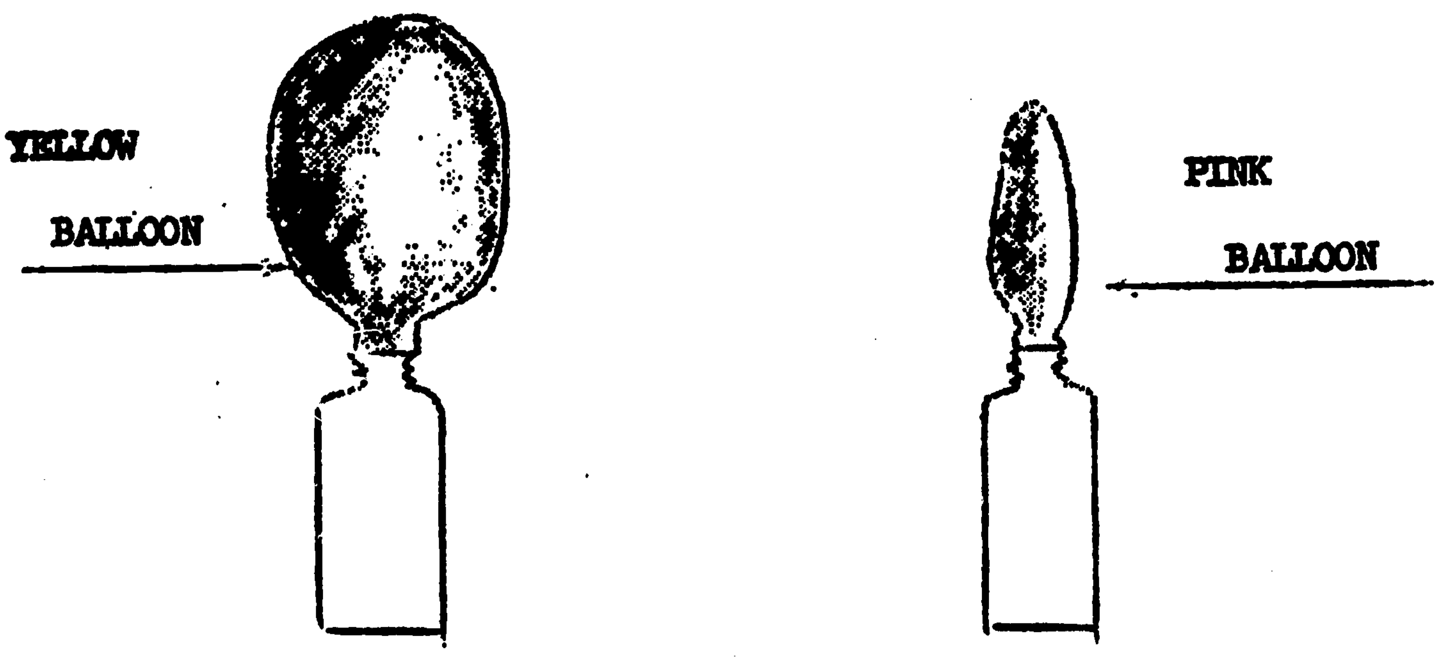
3. Both balloons should have been the same size but the bottle with the yellow balloon contained water which turned to steam when it was heated. The steam made the yellow balloon get larger.

4. The bottle with the yellow balloon was getting more heat than the bottle with the pink balloon. The air and water inside the yellow balloon expanded more and got bigger than the pink balloon.

After you have made a mark by your answer, turn the page and gather clues about the problem.

Here are some clues you might want to gather to help you solve the problem. If you want to know the answers to any of the clue questions, pull the tabs off the answers and put the tabs on the tab card in the order which you pulled them.

A.	If there were water in one of the bottles, would the water turn to steam when the bottle was heated as it was in the film?	YES
B.	Was there water in the bottle with the yellow balloon before the bottle was put on the fire?	YES
C.	Was there anything but air in the bottle with the pink balloon?	NO
D.	Did the color of the balloon make a difference?	NO
E.	Does air expand when it is heated?	YES
F.	Was the yellow balloon easier to blow up than the pink balloon?	NO
G.	Were both balloons receiving the same amount of heat?	YES
H.	Does air and steam take up more space than just air alone?	YES
I.	Did the bottle with the yellow balloon contain something besides air?	YES
J.	If there were steam in one of the bottles, would the steam help the balloon on that bottle to get bigger?	YES



WHY DOES ONE BALLOON GET BIGGER THAN THE OTHER?

Pull the answer tab that you think answers the question most completely. Put the tab on the tab card under the tabs you pulled from the opposite page. If the answer under the tab is a "YES" response, you have correctly answered the question. If the answer under the tab is a "NO" response, then you may go back and gather more information by pulling more tabs from the opposite page. Keep going until you get a "YES" response on this page.

1. The yellow balloon got larger because the bottle with the yellow balloon held more air than the bottle with the pink balloon. Because there is more air in the yellow balloon, the heat makes the air expand more and makes the balloon bigger. NO

2. Both balloons should have been the same size but the bottle with the yellow balloon contained water which turned to steam when it was heated. The steam made the yellow balloon larger. YES

3. The bottle with the yellow balloon was getting more heat than the bottle with the pink balloon. The air and water inside the yellow balloon expanded more and got bigger than the pink balloon. NO

4. The yellow balloon got larger because it was easier to blow up than the pink balloon. NO

STOP

Do Not Go Past This

Page Until You Are

Told To Do So.

WHY DOES THE WATER BOIL THE SECOND TIME?

Put a check mark by the answer that you think is most correct.

1. Suction made the water boil the second time.

2. There was something special in the water and when the cold liquid was poured over the bottle, the water boiled the second time.

3. When hot liquid was poured over the bottle with the cork in it, it heated the water in the bottle and made it boil the second time.

4. When the liquid was poured over the bottle, all of the steam that was in the bottle went out of the top of the bottle. Then because the liquid that was poured over was hot, the water inside the bottle boiled the second time.

5. When the cold liquid was poured over the bottle with the cork in it, it mixed with the hot water and steam in the bottle and made it boil the second time.

6. When the cold liquid was poured over the bottle with the cork in it, the steam in the bottle cooled and turned back to liquid water. Then because there was less pushing on the water and the water was still hot, the water boiled the second time.

After you have made a mark by your answer, turn the page and gather clues about the problem.

Here are some clues you might want to gather to help you solve the problem. If you want to know the answers to any of the clue questions, pull the tabs off the answers and put the tabs on the tab card in the order which you pulled them.

A.	Was the bottle and everything in it cooler after the liquid was poured over the bottle?	YES
B.	When the water boiled the first time did the steam that came from the water push most of the air out of the bottle?	YES
C.	Was the air in the bottle above the water pushing on the water more when the water boiled the first time than it was when it boiled the second time?	YES
D.	Was there something special in the water that made it boil the second time?	NO
E.	Was the water in the bottle still hot when it boiled the second time?	YES
F.	When the cork was put in the bottle, was the bottle filled mostly with steam?	YES
G.	Was the bottle made of glass?	YES
H.	If no cork had been put in the bottle, would the water have boiled the second time?	NO
I.	Will water boil at a lower temperature if there is less pressure on it?	YES
J.	Was the substance water that was poured over the bottle after the cork was put in the top?	YES
K.	Was there less pressure on the water when it boiled the second time than there was when it boiled the first time?	YES
L.	Did the liquid that was poured over the bottle cause most of the steam in the bottle to cool and turn back to liquid water?	YES
M.	Will water boil at a lower temperature if the air above it does not push down on it as hard?	YES
N.	If the air in the bottle did not push down on the water as hard, would the water boil at the same temperature?	NO
O.	Does the cork keep anything from coming in or going out of the bottle?	YES
P.	If the cork had a hole in it so that air could go into the bottle, would the water boil the second time?	NO

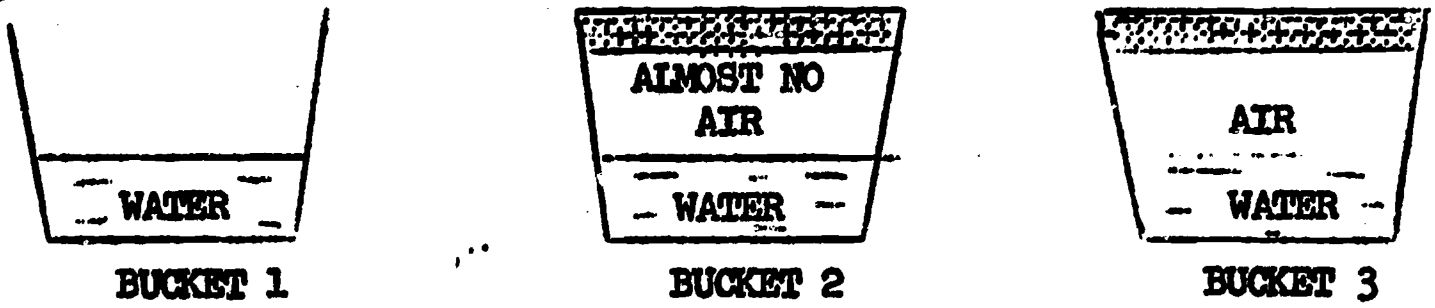
WHY DOES THE WATER BOIL THE SECOND TIME?

Pull the answer tab that you think answers the question most completely. Put the tab on the tab card under the tabs you pulled from the opposite page. If the answer under the tab is a "YES" response, you have correctly answered the question. If the answer under the tab is a "NO" response, then you may go back and gather more information by pulling more tabs from the opposite page. Keep going until you get a "YES" response on this page.

1. When the liquid was poured over the bottle all of the steam that was in the bottle went out of the top of the bottle. Then because the liquid that was poured over was hot, the water inside the bottle boiled the second time.	NO
2. When cold liquid was poured over the bottle with the cork in it, the steam in the bottle cooled and turned back to liquid water. Then because there was less pushing on the water and the water was still hot, the water boiled the second time.	YES
3. When hot liquid was poured over the bottle with the cork in it, it heated the water in the bottle and made it boil the second time.	NO
4. Suction made the water boil the second time.	NO
5. There was something special in the water and when the cold liquid was poured over the bottle, the water boiled the second time.	NO
6. When the cold liquid was poured over the bottle with the cork in it, it mixed with the hot water and steam in the bottle and made it boil the second time.	NO

After you have found the "YES" tab on this page, turn over to the next page and answer two more questions.

A scientist had three buckets like those below:



He put the same amount of water in each of the buckets. He then used a special machine that took all of the air out of bucket 2 and put it in bucket 3. Then he put covers on bucket 2 and bucket 3 to keep anything from coming into or going out of the buckets. He then heated each bucket with the same amount of heat.

<u>QUESTION #1</u>

When will the water boil? Put a check by the answer you choose.

a. It will boil first in bucket 1.

b. It will boil first in bucket 2.

c. It will boil first in bucket 3.

d. It will boil at exactly the same time in all of the buckets.

<u>QUESTION #2</u>

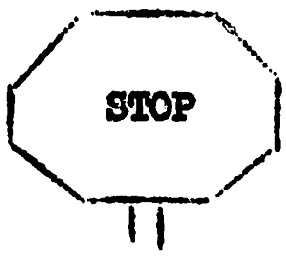
Suppose we take the covers off the tops of the buckets. When will the water boil? Put a check by the answer you choose.

a. It will boil first in bucket 1.

b. It will boil first in bucket 2.

c. It will boil first in bucket 3.

d. It will boil at exactly the same time in all of the buckets.



When You Are Finished

With These Two Questions,

Close the Test Booklet.

DO NOT GO BACK TO OTHER PARTS OF

THE TEST.

TAB TEST

FORM B

THE TAB INVENTORY

OF

SCIENCE PROCESSES

WHY DOES THE BOARD MOVE EASILY AT FIRST BUT NOT LATER?

Put a check by the answer that you think is most correct.

1. The board moves easier at first because it is filled with air. After awhile most of the air is out of the balloon and the board does not move.

2. The board moves easier at first because the air coming out of the balloon pushes the board around the table. After awhile most of the air is out of the balloon and the board does not move.

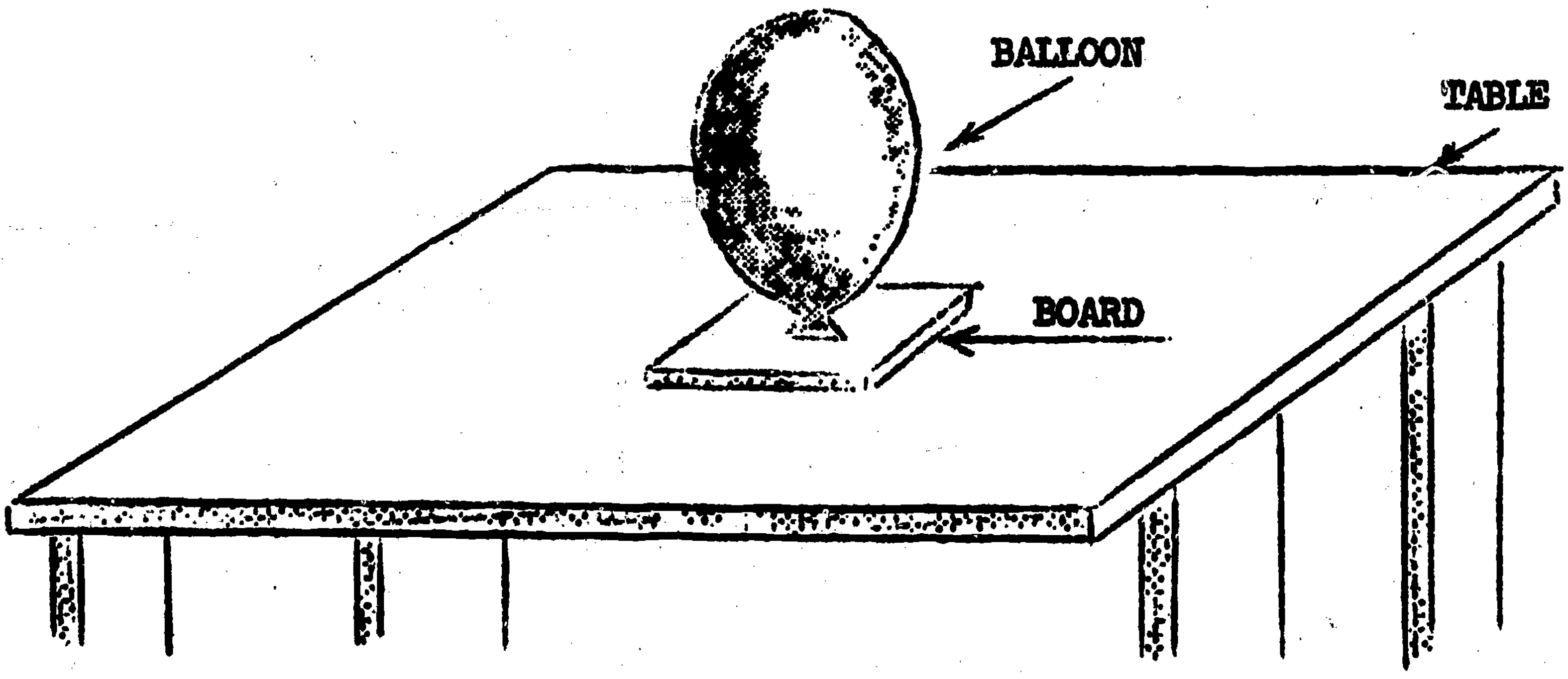
3. The board moves easier at first because the air coming out of the balloon pushes the board up from the table and the woman can push it easier. After awhile most of the air is out of the balloon and the board is touching the table making it harder to push.

4. The board moves easier at first because the air coming out of the balloon comes through a hole in the bottom of the board. After awhile most of the air is out of the balloon and the board does not move.

After you have made a mark by your answer, turn the page and gather clues about the problem.

Here are some clues you might want to gather to help you solve the problem. If you want to know the answers to any of the clue questions, pull the tabs off the answers and put the tabs on the tab card in the order which you pulled them.

A.	If the air coming out of the balloon pushed hard enough could it lift the board up from the table?	YES
B.	Does the air come out of the balloon through one hole in the bottom of the board?	YES
C.	Is there something other than air in the balloon?	NO
D.	Is there something slippery on the table that makes the board slide easier?	NO
E.	At the end of the film was the air coming out of the balloon pushing hard enough to lift the board up from the table?	NO
F.	Is the table slanted?	NO
G.	Was there more air in the balloon at the beginning of the film than there was at the end?	YES
H.	If the woman did not push the board, would it move across the table?	NO
I.	At the beginning of the film was the air coming out of the balloon pushing hard enough to lift the board up from the table?	YES
J.	Would the board move over the table easier if the board and the table were not touching?	YES



WHY DOES THE BOARD MOVE EASILY AT FIRST BUT NOT LATER?

Pull the answer tab that you think answers the question most completely. Put the tab on the tab card under the tabs you pulled from the opposite page. If the answer under the tab is a "YES" response, you have correctly answered the question. If the answer under the tab is a "NO" response, then you may go back and gather more information by pulling more tabs from the opposite page. Keep going until you get a "YES" response on this page.

1.	The board moves easier at first because the air coming out of the balloon pushes the board around the table. After awhile most of the air is out of the balloon and the board does not move.	NO
2.	The board moves easier at first because the air coming out of the balloon pushes the board up from the table and the woman can push it easier. After awhile most of the air is out of the balloon and the board is touching the table making it harder to push.	YES
3.	The board moves easier at first because the air coming out of the balloon comes through a hole in the bottom of the board. After awhile most of the air is out of the balloon and the board does not move.	NO
4.	The board moves easier at first because it is filled with air. After awhile most of the air is out of the balloon and the board does not move.	NO

STOP

Do Not Go Past This Page

Until You Are Told

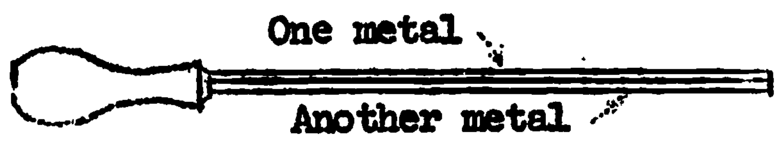
To Do So

WHY DOES THE BLADE BEND AND THEN STRAIGHTEN OUT?

Put a check mark by the answer that you think is most correct.

1. The knife looks like this: 

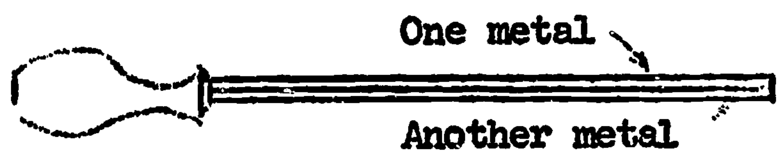
   It is an ordinary table knife like a butter knife. It melts when it is put in the fire and bends. When the knife is put in the liquid it cools and goes back to its normal shape.

2. The knife looks like this: 

   When the knife is heated, the top metal melts and causes the knife to bend. When the knife is put in the liquid, it cools and goes back to its normal shape.

3. The knife looks like this: 

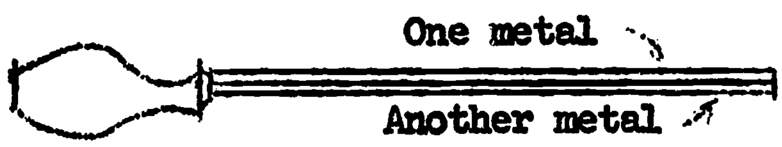
   It is an ordinary knife, like a butter knife. When it is put in the fire the knife expands and bends. When the knife is put in the liquid, it cools and goes back to its normal shape.

4. The knife looks like this: 

   When the knife is heated in the flame, it bends toward the ground because the bottom metal gets smaller and the top metal gets larger. When the knife is put in the liquid, it cools and goes back to its normal shape.

5. The knife looks like this: 

   When the knife is heated, the metals expand the same amount and the knife bends. When the knife is put in the liquid, it cools and goes back to its normal shape.

6. The knife looks like this: 

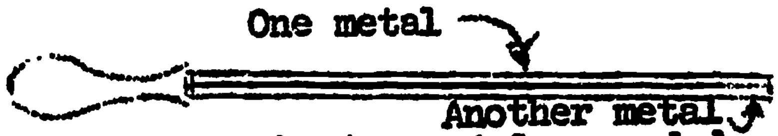
   When the knife is heated, the top metal expands faster than the bottom metal. The bottom metal then pulls the top metal into a curve and the knife bends. When the knife is put in the liquid, it cools and goes back to its normal shape.

After you have made a mark by your answer, turn the page and gather clues about the problem.

Here are some clues you might want to gather to help you solve the problem. If you want to know the answers to any of the clue questions, pull the tabs off the answers and put the tabs on the card in the order which you pulled them.

A. Was the knife made of brass and steel? — YES

B. Look at this knife:



Suppose this knife were heated and the top metal expanded faster than the bottom metal. Would the bottom metal pull the top metal so that the knife bends? — YES

C. Was the knife longer when it was curved than it was when it was straight? — YES

D. Did the flame melt the knife? — NO

E. Was one side of the knife made of one metal and the other side made of another kind of metal? — YES

F. Was the knife made of more than one kind of metal? — YES

G. Was the knife an ordinary table knife? — NO

H. If the knife were made of tin and gold, would the knife bend if it were heated? — YES

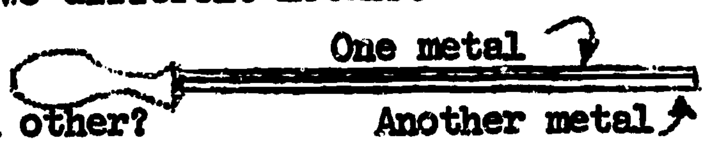
I. Do all metals expand the same amount if they were heated with the same amount of heat? — NO

J. Was the liquid in the tank water? — YES

K. Does one part of the knife expand faster than the rest of the knife? — YES

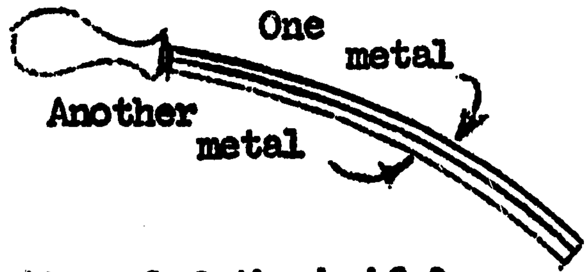
L. Does the knife expand when it is put in the flame? — YES

M. Suppose the knife were made of two different metals:



Would the knife bend if the two metals were not attached to each other? — NO

N. Suppose the knife is bent like this:



Does this mean that the metal on top expands faster than the bottom metal if the knife is heated? — YES

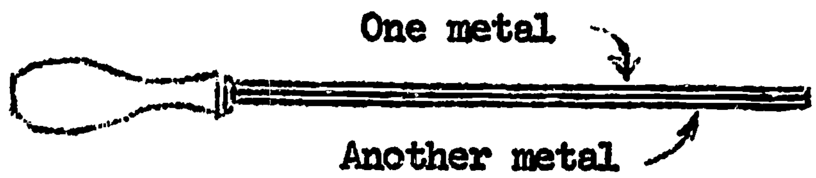
O. Was the liquid in the tank such that it cooled the knife? — YES

P. After the knife was bent, if it would have been allowed to cool without putting it in the liquid, would it have straightened out? — YES

WHY DOES THE BLADE BEND AND THEN STRAIGHTEN OUT?

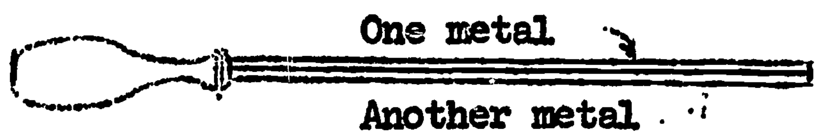
Pull the answer tab that you think answers the question most completely. Put the tab on the tab card under the tabs you pulled from the opposite page. If the answer under the tab is a "YES" response, you have correctly answered the question. If the answer under the tab is a "NO" response, then you may go back and gather more information by pulling more tabs from the opposite page. Keep going until you get a "YES" response on this page.

1. The knife looks like this:



When the knife is heated in the flame, it bends toward the ground because the bottom metal gets smaller and the top metal gets larger. When the knife is put in the liquid it cools and goes back to its normal shape. NO

2. The knife looks like this:



When the knife is heated, the top metal expands faster than the bottom metal. The bottom metal then pulls the top metal into a curve and the knife bends. When the knife is put in the liquid it cools and goes back to its normal shape. YES

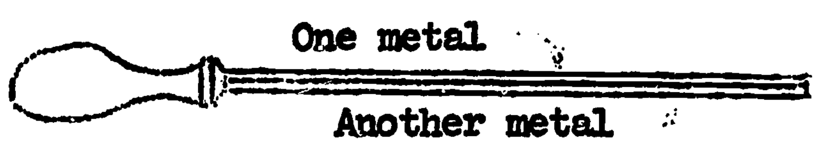
3. The knife looks like this:

It is an ordinary knife, like a butter knife. When it is put in the fire the knife expands and bends. When the knife is put in the liquid, it cools and goes back to its normal shape. NO

4. The knife looks like this:

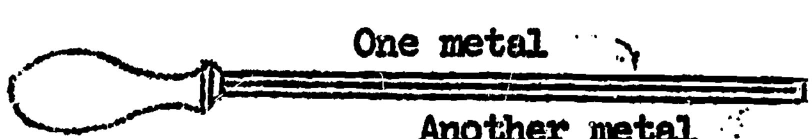
It is an ordinary table knife like a butter knife. It melts when it is put in the fire and bends. When the knife is put in the liquid it cools and goes back to its normal shape. NO

5. The knife looks like this:



When the knife is heated, the top metal melts and causes the knife to bend. When the knife is put in the liquid, it cools and goes back to its normal shape. NO

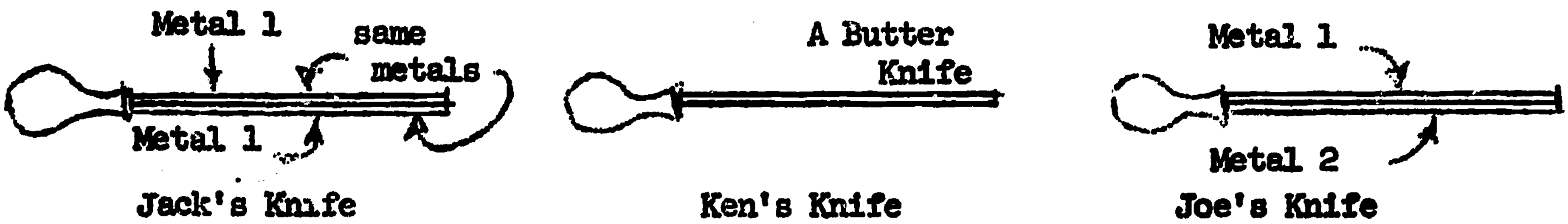
6. The knife looks like this:



When the knife is heated, the metals expand the same amount and the knife bends. When the knife is put in the liquid it cools and goes back to its normal shape. NO

After you have found the "YES" tab on this page, turn over to the next page and answer two more questions.

LOOK AT THESE THREE KNIVES:



The knives are exactly the same size.

We heat all three knives with the same amount of heat.

QUESTION #1

Which knife will bend the most? Put a check by the answer you choose.

a. Jack's knife will bend the most.

b. Ken's knife will bend the most.

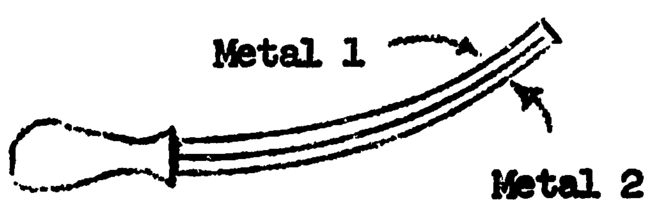
c. Joe's knife will bend the most.

d. All knives will bend the same.

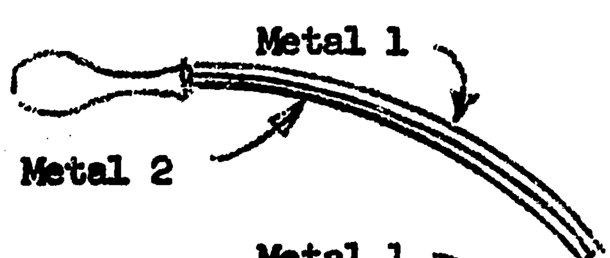
QUESTION #2

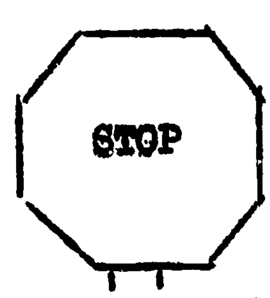
In Joe's knife, metal 2 expands more than metal 1 if they are heated with the same amount of heat. Which way will the knife bend? Put a check by the answer you choose.

I.

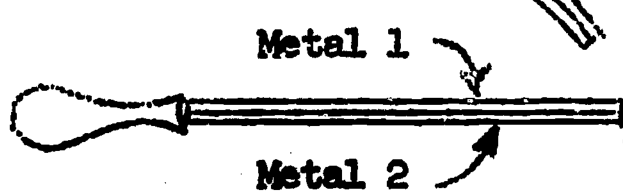


II.





III.



When You Are Finished With These Two Questions Close The Test Booklet. DO NOT GO BACK TO OTHER PARTS OF THE TEST.

APPENDIX B

DIRECTIONS FOR ADMINISTERING

THE TAB SCIENCE TEST

What Is the TAB Science Test?

The TAB Science Test is an instrument which measures the inquiry behaviors of elementary school children in science problem situations. It is a test of not only how much the student knows, but how he can bring to bear on a problem both what he knows and what he can find out. During this test, students will be presented two science problems and enough information to solve the problems. The test measures (1) what information the child chooses to help hmm solve the problem; (2) the productivity of his inquiry, that is, his answer to the problem; and (3) the child's reaction to a similar problem situation.

Administering the TAB Science Test

What is the appropriate form of the test to use? There are two forms of the TAB Science Test--Form A and Form B. Each form is appropriate for elementary school children in grades 4, 5, and 6.

What materials should be assembled before testing? The necessary materials are:

1. An adequate number of TAB Science Test booklets for the number of students to be tested at one time;
2. Two answer sheets, colored yellow and pink for each student;
3. Pencils for all children. PLEASE--NO INK;
4. A timer--any watch or clock.

As the examiner, what is your role during testing sessions? Your role is a more active one than in most testing situations. You must present to the examinees a demonstration of how to take the TAB Science Test. In doing so, you must relate directions word for word, and also answer class questions about the test format. Since the format of the TAB Science Test is unique, it is a learning experience for the child to even take the test.

Time must be kept carefully. Under no circumstances is additional time to be allowed for any student. Time allowances are generous enough to permit most all students to finish.

Directions for Administering the TAB Science Test

Before administering the test, the administrator must procure a copy of the large TAB Science Test similar to that found on the next page.

When the students are assembled in the examination room and seated, say:

> The testing period has begun. There should be no talking until you have been dismissed. We shall now pass out test materials. Do not open your booklet until you are told to do so.

Distribute the test booklets and two answer sheets (one yellow and one pink) to each student.

> At the top of your answer sheet write your name, your teacher's name, your grade, and school. Also, write today's date. Today's date is ________. Next write an A or a B below the date. (Depending on the Form of test being used). Please do not write anything at all in the test booklet. Write all answers on the answer sheet.

Start the directions--use the large TAB Science Test described on this page.

> You may have never taken a test like this. Because it is unusual, it is very important that you pay strict attention to directions. Let's look at the chart.

THE TAB BOOKLET USED TO DEMONSTRATE THE TAB SCIENCE TEST FORMAT

Page 1

One day in class, Mrs. Smith asked Randy to think of a number. What number was it?

1. 9
2. 47
3. 52
4. 150

Page 2

A.	Was the number greater than 100?	NO
B.	Was the number an even number?	YES
C.	Was the number less than 9?	NO
D.	Was the number greater than 47?	YES
E.	Was the number an odd number?	NO
F.	Was the number less than 100?	YES
G.	Was the number less than 52?	NO
H.	Was the number divisible evenly by 3?	NO
I.	Was the number greater than 10?	YES

Page 3

The number that Randy was thinking of was?

1.	47	NO
2.	9	NO
3.	150	NO
4.	52	YES

Read the first page of the chart.

Mrs. Smith asked Randy to think of a number. What number was it?

1. 9
2. 47
3. 52
4. 150

Do you know what number Randy was thinking of? How many think it was 9? 47? 52? 150? How many don't know for sure? I think that you will agree that none of us really knows for sure. We would have to ask Randy. But he is not here.

How then are we going to find out what number Randy was thinking of? This is the nice part about a test such as this, because we can open the booklet and gather some clues that might help us find out what number Randy was thinking of.

Open the large booklet to the middle section.

Here are some clues that might help you solve the problem. For example, the first clue at the top of the page is "A. Was the number that Randy was thinking of greater than 100?" If you want to know the answer to that question, all you do is remove this lettered tab. Under the tab you find a "YES" or "NO" answer. If it is "YES," then the number Randy was thinking of was greater than 100.

Read the rest of the clue questions and then ask?

Do you want to find the answer to the problem? Let's ask some clue questions, and I'll pull off the lettered tabs. When you think you know the answer, we'll turn to the next page (DO SO). On this page you see the four numbers that Randy could be thinking of. Also, on this page are numbered tabs. Under one of the tabs is a "YES" answer. Under the other tabs there are "NO" answers. The idea behind this test is to pull as many clue tabs (ON PAGE 2) as you need and then to pull the "YES" tab from the answer page (PAGE 3).

Let's gather some clues.

Here have the students ask clue questions. The examiner should pull the tabs that the students select. Place the tabs on the chalkboard or on the wall in a column such as

A
G
C

When some students ask to pull the answer tab from the answer page, remind them:

> Are you sure that you know the answer? You can gather as many clues as you need, but you must be certain of your answer. If you pull a tab from the answer page that has a "NO" under it, you will be penalized (some points will be charged against you). Make sure you know the answer.

When all the students are ready to pull the tab from the answer page, remove the tab from the test. Put the tab in the same column with the tabs you removed from the clue page (PAGE 2). Keep pulling answer tabs until the correct answer is found.

> Let's now imagine that you made a mistake and pulled off a tab that had a "NO" under it on the answer page. In this case you put the tab in the same column with the other tabs and keep going until you find the tab with the answer under it.

Have the students turn to their individual TAB Science Tests. Check to see that each student has the correct form of the test; i. e., either A or B. Then have each student ready his yellow answer sheet.

> Turn now to the second page in your test. On this page you should see a question that reads either:
>
> Form A—Why does one balloon get bigger than the other?
>
> or
>
> Form B—Why does the board move easily at first but not later?

I am going to show you a short film. In this film, a lady will perform a scientific experiment. On this page you see four answers that explain the question on the film. After you see the film, you will be asked to choose the answer that you think is correct.

Now look at your yellow answer sheet. There are four numbers on the sheet. If you think that answer number 1 is the correct answer, then you may circle the 1 on the answer sheet. If you think that answer number 2 is the correct one, you will circle number 2. PLEASE WRITE ALL OF YOUR ANSWERS ON THE COLORED PAPER. WRITE NOTHING IN THE TEST BOOKLET.

Have the student turn to the next page--a page in which the clue questions are found.

On this next page you will see a list of clue questions that you might want to ask to help you solve the problem. If you would like to know the answer to any of the questions, pull that tab from the test. Under the tab is the answer. BEFORE YOU PULL ANY TABS FROM THE TEST, READ ALL OF THE QUESTIONS--THE QUESTIONS AT THE BOTTOM OF THE PAGE MAY BE MORE IMPORTANT THAN THOSE AT THE TOP OF THE PAGE.

Have the students turn to the next page.

On this next page you will see a large "STOP" sign at the bottom of the page. On this page are the same answers which were given on the first page of the test. Now you can find out if your clue gathering has been helpful. Under one of the tabs on this page is a "YES" and under three of the tabs are "NO" answers. The secret behind this test is to find the answer on this page that has the "YES" under it.

When you pull a tab from the test, place the tab on the yellow answer sheet in the place marked "TABS." Put all of your tabs in one row.

The examiner might give an example of how this would be done by showing the tabs that were pulled from the large test and placed in a column on the chalkboard or bulletin board. Indicate that even the numbered tabs are to go in the same column.

Do you have any questions?

Have the students turn back to the first page of this section of the test--the page with the numbered explanations and no tabs.

> I am now going to show you a short film. Be sure to watch it carefully.

Show film--Form A: "The Relative Expansion of Air and Water Under Heat"

Form B: "The Air Sled"

As the film is shown, read the question at the beginning of the film.

After the film:

> You now have ten minutes to read the explanations, circle your choice on your answer sheet, gather clues, and find the correct answer. When you are finished, close your books.

Start the test. Time exactly ten minutes. Answer any individual questions related to the test format. Do not answer questions concerning the film.

At the end of ten minutes:

> Everyone should stop now. Take your pencil and copy down the numbers and letters of the tabs in the column beside your tabs on the yellow answer sheet. When you have copied this list, put the tabs back on the test. Be sure that you put the tabs where they belong.

Demonstrate this set of directions with a student's paper.

When everyone is ready for the next part, collect the first set of answer sheets.

> Now let's get our second answer sheet ready.
>
> Turn to the next test in the book. On this page you will notice a question at the top of the page:

Read the question.

> Form A--Why does the water boil the second time?
>
> Form B--Why does the blade bend and then straighten out?

On this page, you will notice there are six explanations. The same rules apply: after seeing the film, you will read the explanations on this page and select the one that you think is right. You will then circle that number on your pink answer sheet.

Have the students turn to the next page.

On this page you will notice some clue questions. Once again, read all of the clue questions before you pull any tabs. When you pull any tabs, put them in the "TABS" column.

Have the students turn to the next page.

On this page there are the answers to the problem. When you are ready to pull a tab from this page, pull the tab and put it in the "TABS" column. Keep pulling tabs from this page until you find the tab that has the "YES" answer under it.

Have the students turn to the next page.

On the last page in the book there are two more questions to answer. Read the entire page from top to bottom and answer these two questions by circling a number or letter on your pink answer sheet where you see "Question No. 1" and "Question No. 2."

Have the students turn back to the first page of this section of the test--

to the page with the numbered explanations having <u>no</u> tabs.

I am now going to show you a short film. Watch it carefully.

Show the film.

Form A--Boiling Water by Cooling

Form B--The Bimetallic Strip

After film:

You now have fifteen minutes to read the explanations, circle your choice on your answer sheet, gather clues, find the correct answer, and answer the two questions on the last page. When you are finished, close your book.

Start the Test. Time exactly fifteen minutes. Answer questions related to test format. Answer no questions dealing with the film.

At the end of ten minutes:

> Everyone should stop now. Take your pencil and copy the numbers and letters of the tabs in the column beside your tabs on the pink answer sheet. When you have copied this list, put the tabs back on the test. Be sure that you put the tabs back where they belong.

Collect answer sheets and booklets.

APPENDIX C

Each of the questions and explanations found in the TAB Science Test was analyzed by a panel of judges. The following set of instructions was given to each judge as criteria:

There are two separate forms of the TAB Science Test under development. Form A will include pages 5, 6, 7, 8, and 9 of this questionnaire. Form B will include pages 10, 11, 12, 13, and 14. Each form of the test (A and B) is composed of two separate sections or sub-problems. In Form A the problems deal with (1) a sliding board on a table and (2) boiling water by cooling. The problems in Form B are (1) the relative expansion of air and water and (2) the bimetallic strip. Each of these four problems can be divided into sub-sections; (1) a page of proposed solutions to the problem; (2) a series of clue questions; (3) a page of explanations in which the child may search for the "correct" explanation; and (4) a page of transfer questions.

I am asking you to:

A. Categorize each question on the following pages in terms of the criteria found on pages 2 and 3. That is, each of the questions should be categorized as either a Type I, II, III, or IV question. Please - - one category per question.

B. Categorize each question on the following pages in terms of the criteria found on page 4. That is, each of the questions should be categorized as either a relevant, additional, or irrelevant question. Please - - one category per question.

C. Check each statement or question on pages for scientific accuracy.

D. Order the explanations in each of the four sub-problems in terms of accuracy. That is, rank the explanations, giving the most correct explanation the score of 1, the next most correct a score of 2, etc.

NOTE: Each of the questions on the following pages has been gathered from individual interviews or from classroom Inquiry Sessions. They will be randomized at a later time when semi-final forms of the TAB Science Test are established.

Thanking you for your cooperation.

SUMMARY SHEET FOR ANALYSIS OF STYLES OF THINKING

1. Verification Questions.

All questions used to identify the parameters of the problem episode, (objects, conditions, events).

A. Type I. (Suchman's Categorical-Verification)

Identification of objects or events in terms of categories into which the perceived whole can fit.

B. Type II. (Suchman's Analytical-Verification)

Questions that are used to analyze objects or events in terms of their component parts, conditions, properties, or relationships.

II. Implication Questions

Questions in search of relationships between variables.

A. Type III. (Suchman's Abstract-Conceptual)

Conceptualized relationships asked about in abstract terms.

B. Type IV. (Suchman's Concrete-Inferential)

Questions that are asked to obtain concrete data through experimental manipulation of variables. The child then makes inferences from the data.

QUESTION TYPE	EXAMPLE
I.	Verification of A. (Was the blade a knife?) (Was A special? Ordinary?) (Was that an ordinary knife?)
II.	Comparing B with A. Specific Questions. (Was the blade hot when it was bent?) Relationships between two questions. (Was the blade longer after it was heated than before?) Relationships between parts of the structural whole. (Was the blade half one metal and half another?) Properties check. (Can a Bunsen burner melt brass?)
III.	Diffuse. (Does the cork have anything to do with the water boiling the second time?) Directed. (Does A affect B?) (Does the cork keep the pressure higher inside the flask?) (Was A the only thing to do with B?) (Was A such that B?) (In general, can A cause B?)
IV.	Elimination. (If the cork were not used at all, would the water boil the second time?) Substitution. (If A were substituted for B, would C?) Addition. (If you put ink in the water, would the water boil the second time?) Necessity. (Was it necessary to pour water on the flask to make the water inside boil the second time?)

Note: These specific examples were taken from Suchman (1962).

In an attempt to determine the relative value of each question on the TAB Science Test, it is important that each question be categorized in terms of its pertinence to the correct solution of the problem.

Please evaluate each question in terms of the following criteria:

1. A Relevant Question - - Provides information which is pertinent or essential to the solution of the problem. A proficient inquirer would utilize this information.

2. An Additional Question - - Provides extra information that a less proficient inquirer might need for the solution of the problem but that a highly proficient one could infer from either the filmed description of the problem or the relevant questions.

3. An Irrelevant Question - - Provides information which is completely unrelated to the solution of the problem. Only an inquirer with a low degree of proficiency would utilize this information.

Each clue question on the TAB Science Test was categorized by a panel of judges in terms of the criteria found in Appendix C. The results of this analysis are presented below and on the following pages.

PART A-1 Why does One Balloon Get Bigger Than the Other?

Question	Question Type	Question Value
A	IV	Relevant
B	II	Relevant
C	II	Relevant
D	II	Irrelevant
E	III	Relevant
F	II	Additional
G	II	Additional
H	III	Relevant
I	II	Relevant
J	IV	Relevant

PART B - I Why Does the Board Move Easily at First But Not Later?

Question	Question Type	Question Value
A	IV	Relevant
B	II	Relevant
C	I	Additional
D	II	Irrelevant
E	III	Relevant
F	II	Additional
G	II	Additional
H	IV	Relevant
I	III	Relevant
J	IV	Relevant

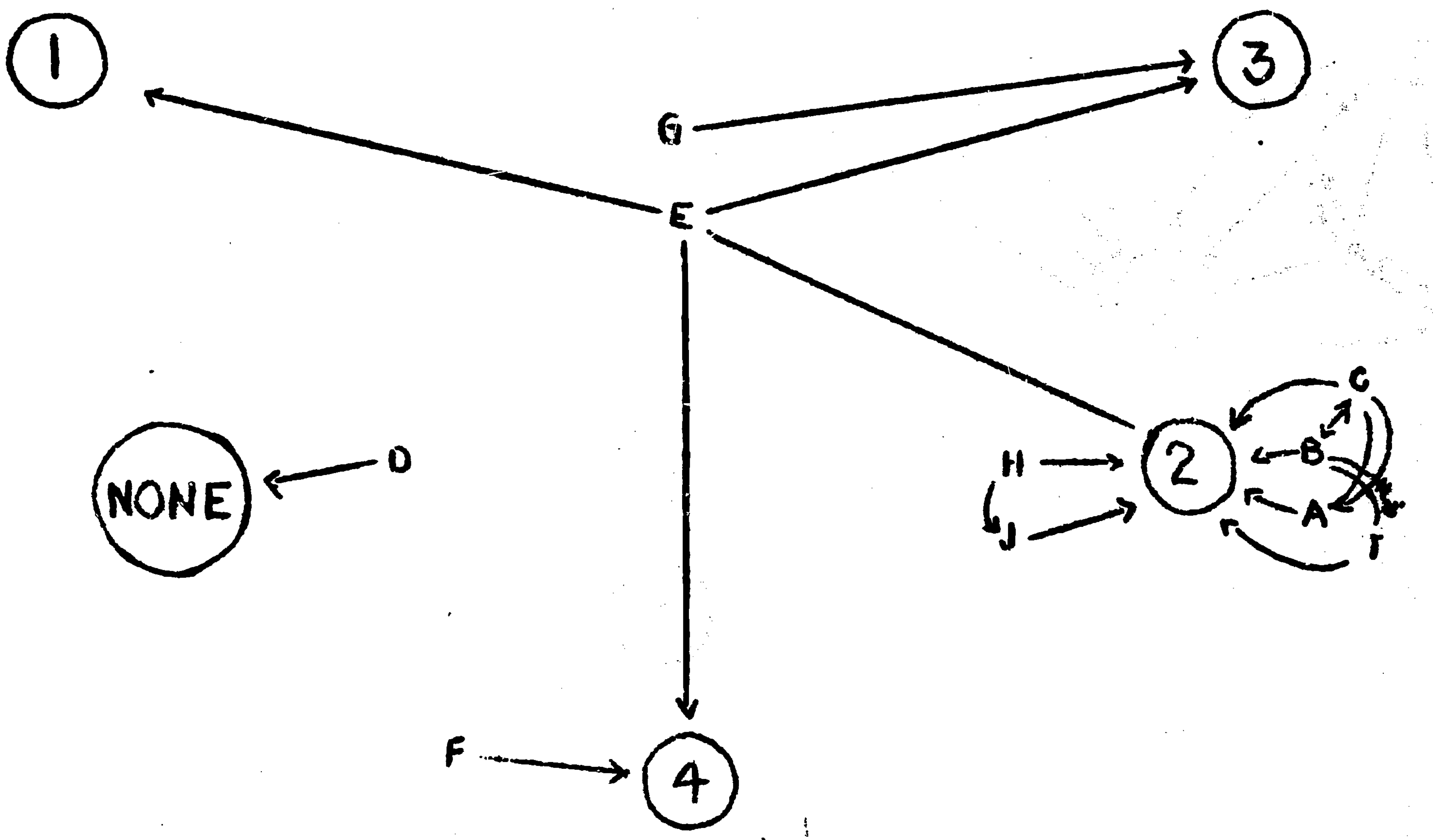
PART A-2 Why Does the Water Boil the Second Time?

Question	Question Type	Question Value
A	II	Additional
B	III	Relevant
C	II	Relevant
D	III	Relevant
E	II	Additional
F	II	Relevant
G	I	Irrelevant
H	IV	Relevant
I	IV	Relevant
J	I	Irrelevant
K	II	Relevant
L	III	Relevant
M	IV	Relevant
N	IV	Relevant
O	III	Additional
P	IV	Relevant

APPENDIX D

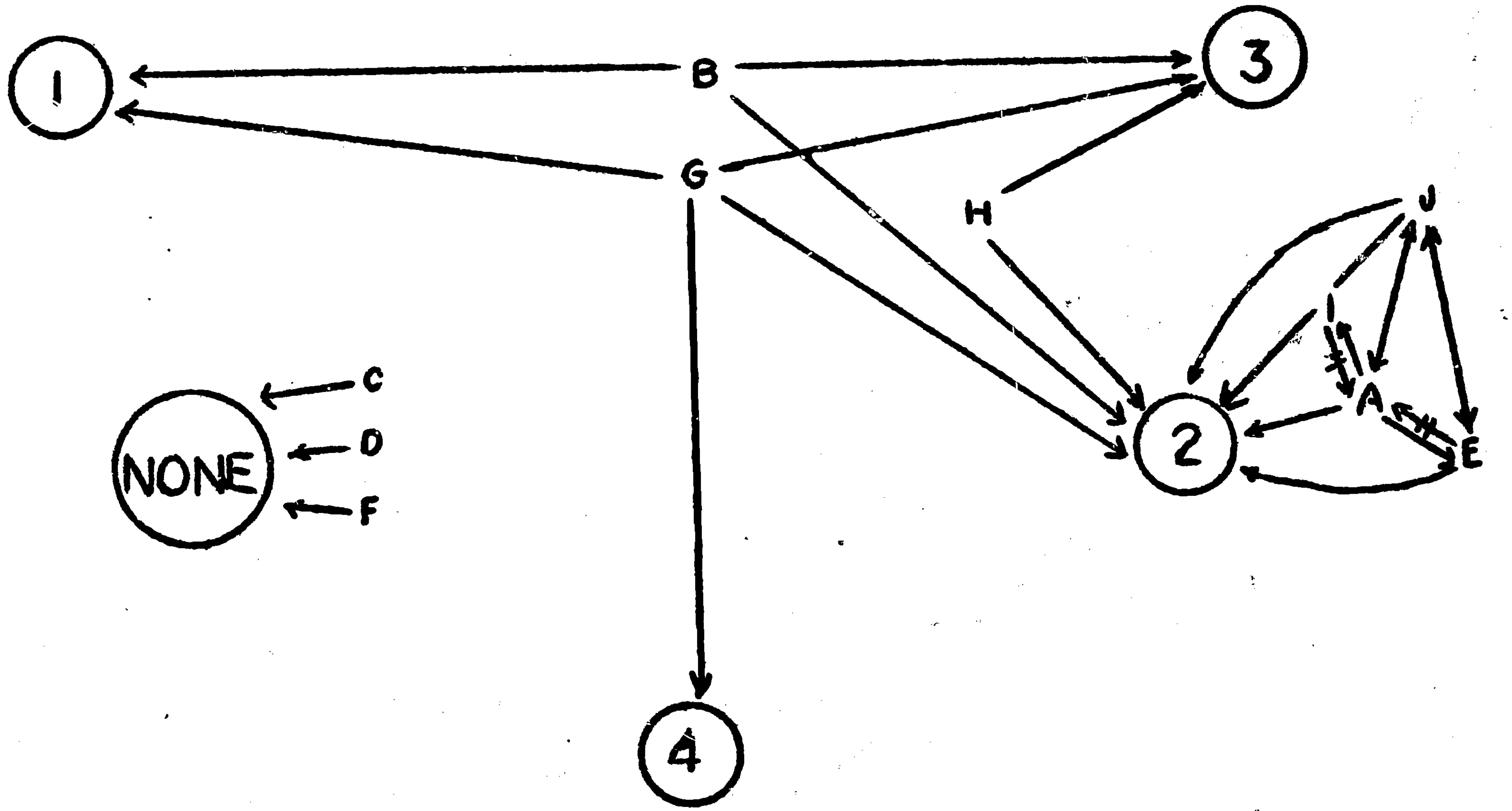
SYSTEM ANALYSIS OF TAB SCIENCE TEST

PART A-1



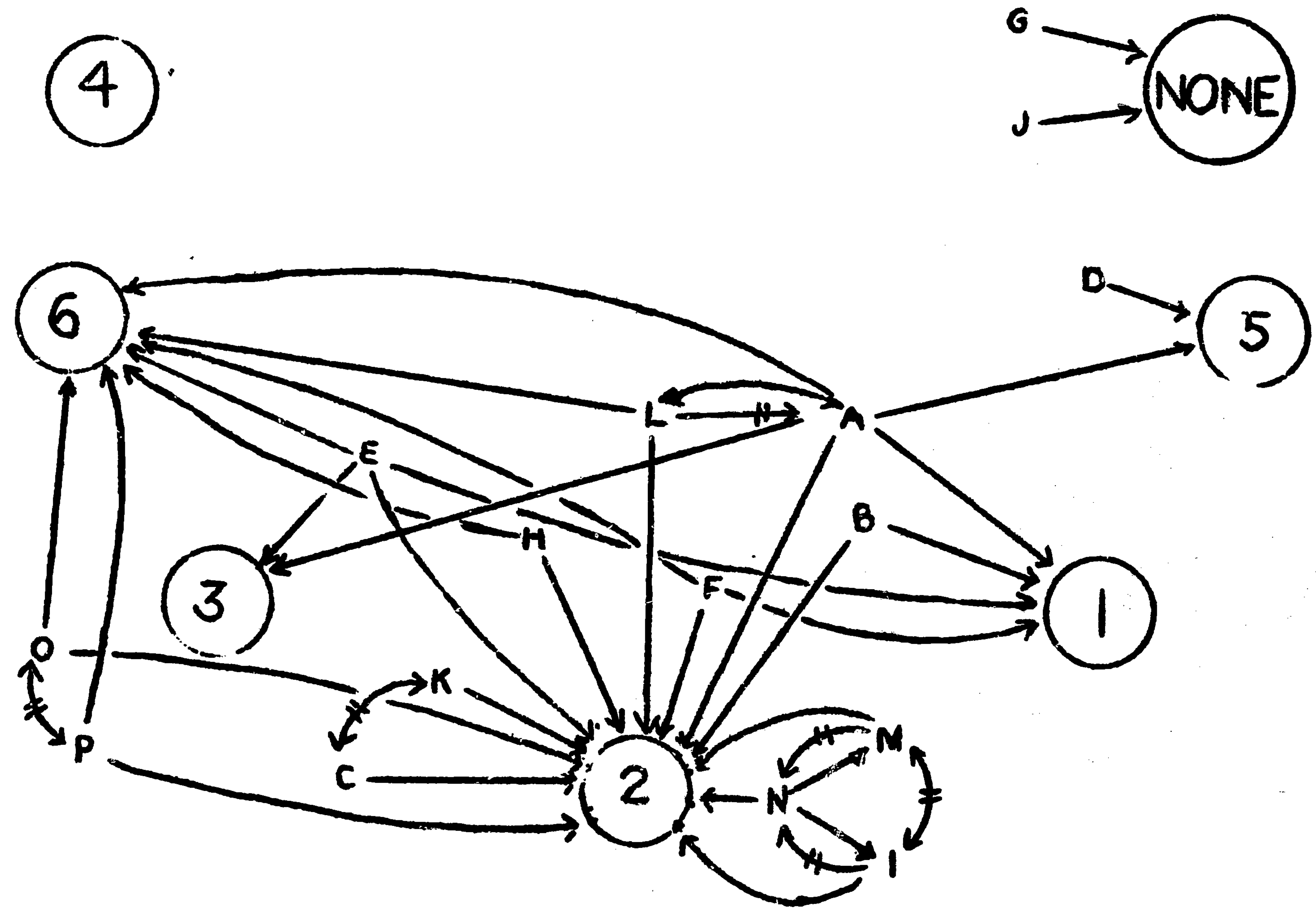
SYSTEM ANALYSIS OF TAB SCIENCE TEST

PART B-1



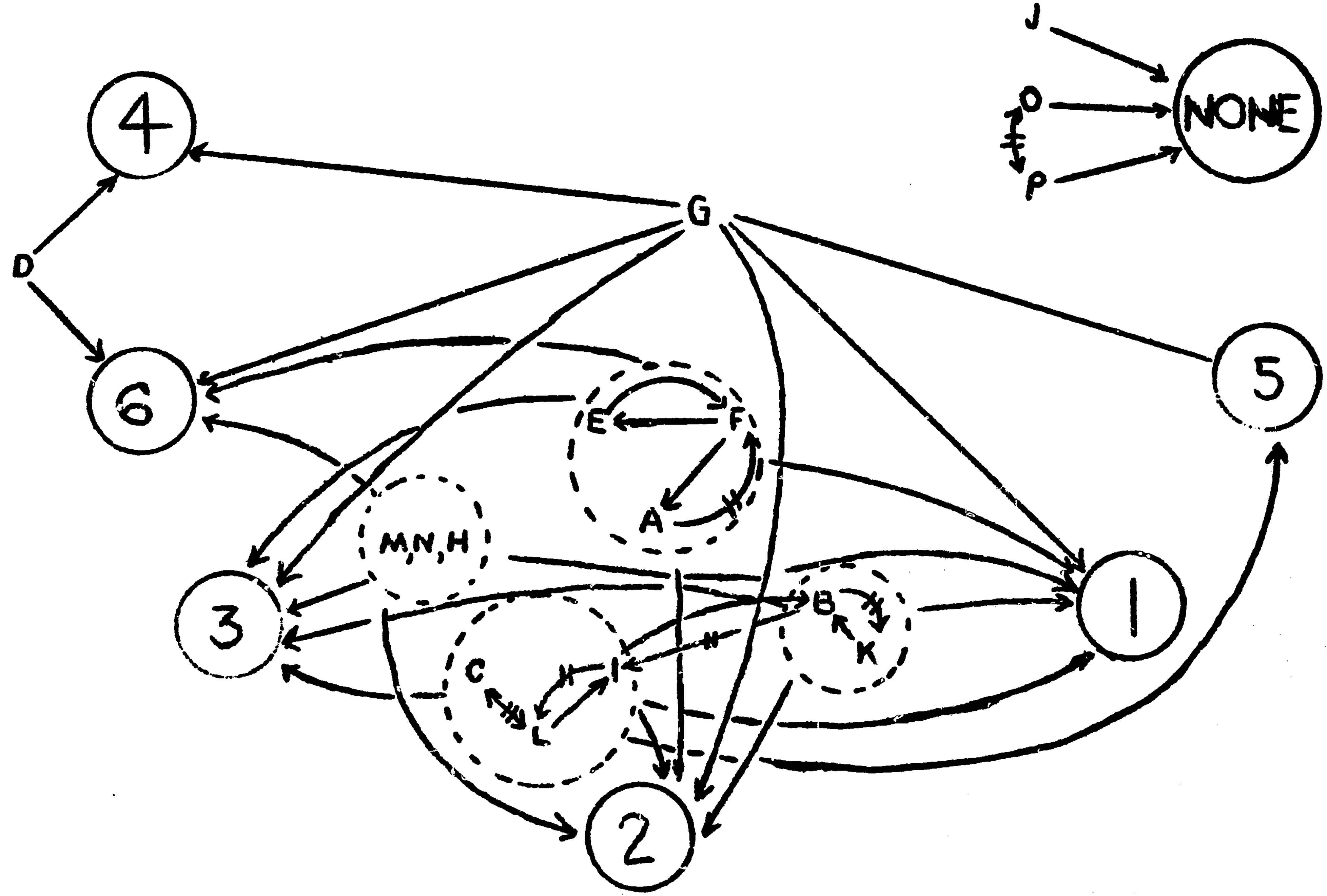
SYSTEM ANALYSIS OF TAB SCIENCE TEST

PART A-2



SYSTEM ANALYSIS OF TAB SCIENCE TEST

PART B-2



APPENDIX E

CONVERSION TABLE

RAW SCORES ON TAB SCIENCE TEST TO T-SCORES

Form A Raw Score	T-Score	Form B Raw Score
16 and below	19	
	19.5	
	20	
18-21	20.5	18 and below
30-36	22	19-23
37-50	22.5	24-29
51-56	23	30-34
57-63	23.5	35-39
64-70	24	40-45
71-77	24.5	46-50
78-84	25	51-55
85-90	25.5	56-61
91-98	26	62-66
99-105	26.5	67-71
106-112	27	72-76
113-119	27.5	77-82
120-125	28	83-87
126-133	28.5	88-92
134-139	29	93-97
140-145	29.5	98-102
146-153	30	103-108
154-160	30.5	109-113
161-167	31	114-118
168-172	31.5	119-124
173-179	32	125-129
180-188	32.5	130-134
189-195	33	135-139
196-203	33.5	140-145
204-208	34	146-149
209-215	34.5	150-154
216-222	35	155-160
223-227	35.5	161-164
228-232	36	165-170
233-237	36.5	171-175
238-243	37	176-181
244-248	37.5	182-187
249-253	38	188-192
254-257	38.5	193-197
258-261	39	198-201
262-265	39.5	202-206
266-268	40	207-213

Form A Raw Score	T-Score	Form B Raw Score
269-271	40.5	214-218
272-274	41	219-222
275-276	41.5	223-226
277-278	42	227-229
279-281	42.5	230-233
282-283	43	234-236
284-285	43.5	237-239
286-288	44	240-242
289-290	44.5	243-245
291-292	45	246-248
293-294	45.5	249-252
295-297	46	253-255
298	46.5	256-258
299-300	47	259-262
301-302	47.5	263-264
303-305	48	265-266
306	48.5	267-269
307	49	270-271
308-309	49.5	272-273
310-311	50	274-275
312-313	50.5	276-278
314-315	51	279-281
316-317	51.5	282-283
318-319	52	284-285
320	52.5	286-288
321	53	289
322	53.5	290-291
323	54	292-293
324-325	54.5	294
326	55	295-296
327	55.5	297-298
328	56	299
329	56.5	300
330-331	57	301-302
332-333	57.5	303-304
334	58	305-306
335	58.5	307-308
366-337	59	309-310
338	59.5	311-312
339	60	313
340	60.5	314
341	61	315-316

Form A Raw Score	T-Score	Form B Raw Score
342	61.5	317
343	62	318
	62.5	319
344	63	320-321
345	63.5	322-323
346	64	324
347	64.5	325
348	65	326-327
349	66	328
	66.5	329
350	67.	
	67.5	330
351	68.	331
352	68.5	332
	69	
353	69.5	333
354	70	334
355	70.5	
	71	
356	71.5	335
	72	
	72.5	336
357	73	
358	73.5	337
	74	
359	74.5	338
	75	
360	75.5	339
	76	
	76.5	340
361	77	
	77.5	341
362-363	78	
	78.5	
	79	342
	79.5	
	80	343
	80.5	
	81	
	81.5	344
	82	
	82.5	345-346